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XIII.

THE MANUFACTURE OF OPEN HEARTH STEEL CASTINGS.

By Passed Assistant Engineer R. T. Hall, U. S. Navy.

Read before the Philadelphia Branch of the Society at their meeting April 24th, 1889, Chief Engineer L. W. Robinson, U. S. Navy, in the Chair.

Cast steel is fast supplanting, in general use for machinery, both cast and wrought iron. It is superior to cast iron, being more homogeneous and of greater strength, and is cheaper to produce than wrought iron forgings.

The relative cost of steel castings, compared with steel and wrought iron forgings, may be taken approximately as follows:

Cast steel, 8 to 20 cents per pound.

Wrought steel, 40 to 45 cents per pound.

Wrought iron, 10 to 25 cents per pound.

The cost of cast steel depends upon the coring and fitting the moulds require, the tensile strength and elongation, and also the amount of phosphorus desired. A low phosphorous steel necessitates the use of a purer and more expensive grade of stock in the charge.

Much prejudice once existed against the use of steel castings, particularly for machinery, because of their supposed uncertain soundness; but such superior metal is now produced that this prejudice has about disappeared.

"Steel castings" is an interesting subject from a professional standpoint; but, owing to the comparative infancy of the industry and the air of mystery that pervades the steel foundry, very little on this subject has been published, and one's information has to be gleaned principally by observation.

Naturally the moulds are the first parts to be considered. They are made in ordinary iron flasks, with cope and drag, each fitted with numerous traverses to assist in holding the sand, because of the small cohesive power of the materials used in making it.

Iron flasks are invariably used, owing to the intense heat to which they are subjected while in the drying oven and also during the pouring.

A highly refractory sand (usually sand from Masillon, Ohio, the article from which grindstones are made), and also finely ground coke are used for facings. These facings are made cohesive by mixture with some adhesive liquid, such as molasses and water, or stale beer. To this is added common flour or pulverized sand to make the surfaces smooth. Stale beer is much used, as it quickly evaporates, leaving its adhesive properties behind.

A layer of facing sand from three to ten inches thick is carefully pressed about the pattern. A porous loam is used to fill the flask and support the facing, and is tightly rammed to give the mould solidity. From eight to eighteen inches space is allowed between the pattern and flask (the amount depending on the weight of the casting) in order to prevent the leakage of molten metal.

When green the moulds are fragile, and great care is required in drawing the patterns. They are loosened by tapping, after the adjacent sand has been dampened with water, and then carefully lifted so as to prevent tilting.

The entire surface of the mould is pierced with nails, the nail-

heads being left flush with the surface, thus forming a strong support for the facing sand after the moulds are dried.

The washes cover the surfaces, and are invariably of some kind of carbon, frequently graphite mixed with some mucilaginous substance, and applied with a brush or swab in thin, even coats. When baked this leaves a smooth and porous coating.

Particular attention is paid to venting the moulds, so that the hot gases resulting from combustion and decomposition may escape as soon as formed by the heat of the entering metal. Large and more numerous vents are placed at the irregular portions of the moulds where the metal is more confined, the heavier parts being in a great measure vented by the openings for the feeding heads.

The shrinkage in steel castings is irregular and uneven, the contraction being from three-eighths to five-sixteenths of an inch per foot; but there is no fixed rule. Experience alone can decide the location and the amount of increased thickness to be allowed in fitting up a pattern. For example, in the casting of an ordinary engine bed plate, consisting of a top and bottom flange and a connecting web, the tendency of shrinkage would be to cause the metal to leave the web, as it were, and seek the flanges, thus making the web thinner. Consequently a greater allowance must be made for shrinkage at the web, and the pattern at that point would accordingly be made heavier.

Orifices for feeding heads are usually placed beside the heavier parts, and, being filled with metal when the mould is poured, it is from them that the metal is drawn to supply the contraction in the casting. The pressure due to the weight of metal in the feeding heads materially increases the density of the metal, if not the soundness of the casting.

It is preferable, when practicable, to feed the moulds from the bottom by a long fountain extending above the mould, giving, as it is often called, "a big head" to the metal.

Cylindrical cores are made upon a hollow iron mandrel, perforated with holes to give vent, covered with hay rope and sand. The surface of the core is protected by nails and carbon wash, like the surface of the mould. Additional vents are sometimes

made in large cores by laying in longitudinal rods while the core is being swept up, and withdrawing them after it is finished.

Irregularly shaped cores are made, usually in boxes, upon a base of small coke and cinder. This gives them great porosity.

The drying ovens are of brick; they are roomy and accessible by tracks. All molds and cores are thoroughly baked and the metal poured while they are as hot as it is possible to keep them.

The Siemen's regenerative gas furnace (and its different forms known as the Lash, the Riley, &c.,) is in general use for making open hearth steel. A regenerative gas furnace consists of two essential parts—the gas producer, in which the fuel, usually coal, is converted into a combustible gas, and the furnace with its two pairs of regenerators for storing the waste heat of the flame and giving it up to the incoming air and gas. By a system of valves the course of the gas is changed at will from one pair of regenerators to the other, usually every twenty or thirty minutes. The air, brought in by another duct, combines with the hot gas just before entering the combustion chamber. The chamber in which the metal is reduced is usually rectangular in plan (about eighteen by fifteen feet for a fifteen-ton furnace). The hearth is depressed in the middle, and by a similar depression in the roof of the combustion chamber, the burning gas is deflected upon the surface of the metal.

The openings in the ends of the furnace serve for admission and discharge of the gas, changing their function when it is desired to change the direction of flow, which is done to keep an even temperature throughout the furnace and to secure the benefit of the regenerators. There are three charging doors on one of the longer sides, and a tap hole on the opposite one, from which the fluid metal is drawn.

The ladle is lined with fire brick or ganister. A conical plug of graphite fits into the graphite bushing of a hole in the bottom of the ladle and has an iron shaft covered with fire clay, or sleeves of fire brick, extending through the interior of the ladle. By a gear on the outside of the ladle, similar to the gear for working poppet valves by hand, the flow of metal through the bottom of the ladle is regulated. By this means only the clear and the

hottest metal from the bottom of the ladle reaches the moulds, and tilting is avoided. The ladle is heated before filling by placing it upside down over a gas stove or coal fire.

The component parts of the usual charge from which open hearth steel castings are made are as follows:

Plate scrap iron (selected scrap).

Open hearth steel scrap, usually from runners and feeders of steel castings broken into a convenient size. It is higher in phosphorus than the castings to which it belonged, the feeders and runners being the highest parts of the mould.

Castle pig, a species of pure iron made from foreign ores.

Spiegeleisen, an alloy of iron, carbon and manganese of definite proportions, which is used to secure the desired amount of carbon and also the deoxidizing effect of the manganese.

Ferro-silicon, which is used because of its beneficial action in preventing blow holes, and increasing the hardness of the steel without decreasing its toughness and malleability when cold.

Ferro-manganese, which is used instead of spiegeleisen because of its large percentage of manganese and low carbon, thereby enabling any desired percentage of manganese to be put in the steel without increasing the amount of carbon, as would be the case should spiegeleisen be used. The manganese is used on account of its great affinity for oxygen, thus preventing the retention of iron oxide in the steel.

Wash-metal and charcoal blooms are frequently used when low phosphorus is required. Wash-metal is ordinary pig iron with its phosphorus low, the greater portion having been removed by running the molten metal over a hearth of lime in an ordinary furnace.

When the metal is wanted for pouring, the furnace is first heated by a wood fire, and, when hot, the gas is turned on and the metal charged.

The ferro-manganese, however, is held back until shortly before "tapping time." Proofs are periodically drawn from the furnace, and analyzed to ascertain the amount of carbon. Twenty or thirty minutes before tapping, the ferro-manganese is added, and makes the steel more fluid in pouring. The specific chemical

action of manganese has not been definitely ascertained, only slight traces of metallic manganese having been found in cast steel. The bulk of the manganese in the charge is found combined with oxygen, silicon and alumina in the slag.

The moulds are placed as near the furnace as possible. Time is a most important element in pouring, and none is lost in getting the metal from the furnace to the mould, the average time from filling the ladle to pouring first mould being about twenty seconds. When the metal in the feeding heads and runners has ceased sinking, the flow of metal is stopped and the ladle passed on to the next mould.

About five minutes after pouring, when the metal in the moulds has set, all the clamps and fastenings on the flasks are removed, and the flasks themselves loosened so that the casting can contract or warp without restraint. The cores are also cooled as soon as possible, and frequently water from a hose is run into a coke and cinder core to chill and set the interior part of the casting first, so that any further changes are compelled to take place on the outside, from whence all resistance has been removed by breaking the flasks.

With castings treated in this manner hair cracks do not occur, and any improper strain on the metal will show itself in a rupture sufficiently wide to admit one's hand. On the contrary, when steel castings are allowed to cool very slowly under the strain of the moulds that were originally intended only to give the casting shape and simply hold the weight of the metal contained, all sorts of invisible defects may be anticipated.

The principal advantage claimed for the slow cooling method is that the castings when cold are perfectly annealed. When the percentage of carbon runs above .16 of one per cent., and when the castings are rapidly cooled, they are usually annealed. This is done by heating the casting to about a cherry-red color and allowing it to cool slowly in the annealing furnace. This merely removes any temper that may be in the metal, and is different from the process wherein the carbon is reduced by heating the metal in an oxide ore, which is the opposite of cementation.

CHARGE.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Plate scrap.....pounds...	500	4,000	3,400	1,500	3,700	1,000	10,000	4,000	3,500	600
Open hearth scrap.....pounds...	800	9,600	13,500	16,200	10,800	15,000	6,800	9,600	9,200	16,800
Castle pig .....pounds...	3,200	2,600	1,500	1,330	2,600	1,000	3,759	1,350	2,500	1,700
Wash metal .....pounds...	3,200	2,600	.....	.....	.....	.....	.....	1,350	.....	1,700
Charcoal blooms.....pounds...	3,350	2,000	.....	.....	.....	.....	.....	.....	.....	.....
Spiegeleisen .....pounds...	720	660	600	600	530	540	700	660	480	660
Ferro-silicon.....pounds...	500	440	280	400	265	360	440	440	300	440
Ferro-manganese.....pounds...	330	330	280	300	265	270	330	330	240	330
PHYSICAL TESTS.										
Name of casting.....	Piston.	A hull casting.	Reversing arms for engine.	Piston.	A hull casting.	Eccentric strap.	Piston.	Piston.	A hull casting.	Piston.
Distance between reference marks in inches.....	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
Original diameter in inches.....	.805	.800	.814	.808	.810	.810	.805	.800	.810	.805
Diameter in inches after fracture.	.560	.550	.593	.695	.760	.550	.745	.580	.725	.740
Original area in square inches....	.5089	.5026	.5204	.5127	.5153	.5153	.5089	.5026	.5153	.5089
Area in sq. inches after fracture.	.2463	.2375	.2761	.3793	.4336	.2375	.4359	.2642	.4128	.4300
Elastic limit, lbs., gauge, load...	16,000	17,000	18,000	21,000	20,000	15,000	15,000	15,000	18,000	17,000
Elastic limit, lbs., per sq. inch..	31,440	33,824	34,588	40,954	38,810	29,109	29,671	29,844	34,931	33,405
Ultimate tensile strength, lbs., gauge, load.....	33,139	31,200	33,500	35,500	38,150	32,500	32,900	32,300	36,600	34,230
Ultimate tensile strength, per square inch	65,118	62,077	64,432	69,241	74,032	63,070	64,649	64,265	71,026	67,262
Elongation in 8 inches.....	2.2	1.75	2.12	1.66	.92	2 0	1.25	2.1	1.26	1.50
Per cent. elongation in 8 inches.	27.50	21.87	26.50	20.75	11.50	25.	15 62	26.25	15.75	18.75
Per cent. reduction of area.....	51.60	52.74	46.94	26.01	11.90	53.91	14.34	47.43	4.8	15.50
Character of fracture.....	fibrous.	fibrous.	fibrous and crystalline.	fibrous and fine crystals.	close crystals.	crystalline and fibrous.	crystalline and fibrous.	crystalline and fibrous.	fine crystals.	crystalline and fibrous.
Cold bending test, around a 3-inch pin.....	180° without fracture.	180° without fracture.	180° without fracture.	180° without fracture.	160° without fracture.	180° without fracture.	180° without fracture.	180° without fracture.	150° without fracture.	180° without fracture.
CHEMICAL ANALYSIS.										
Carbon.....per cent...	.82	.19	.13	.18	.16	.18	.19	.15	.13	.16
Silicon .....per cent...	.23	.18	.23	.13	.17	.25	.20	.15	.32	.21
Manganese .....per cent...	.89	.70	.69	.74	.73	.64	.86	.54	.69	.82
Phosphorus.....per cent...	.05	.054	.068	.069	.07	.071	.071	.073	.074	.074
Sulphur .....per cent...	.06	.037	.04	.052	.03	.042	.06	.045	.045	.053

Test specimens are taken either from the feeding heads or from coupons attached to the casting. Frequently the coupons are required to be cast adjacent the lower edge of the casting, and in this way a sample of the densest metal in the mould is obtained.

The description of the testing machines and the modes of making the tests has been so ably and so often detailed in papers on the subject that any further description is unnecessary here.

The preceding is a table of charges, with the physical tests and chemical analyses of the steel made therefrom, from which the effects of the varying amounts of carbon, silicon, manganese and phosphorus can be investigated.

For example:—In columns I and II will be found the data of charges from which steel low in phosphorus (.05 and .054 of one per cent.,) was produced, while in column VI will be found the data of a charge, the stock of which cost in all probability one-third less than the stock of I and II, from which steel was produced with the resulting tests practically the same, but the amount of phosphorus about .02 of one per cent. greater.

That phosphorus is a weakening element in steel few will deny, but it is doubtless a debatable question whether an increase of .02 of one per cent. of phosphorus, other things being equal, seriously injures the piece of machinery for which the casting was made.

XIV.

STEEL CASTINGS.

By Passed Assistant Engineer Ira N. Hollis, U. S. Navy.

The manufacture of steel for castings and forgings is well understood, and only a brief account of the steps in the open hearth and crucible processes will be necessary in this paper, which deals mainly with the practical methods of making castings.

The open hearth process is best explained by the history of a heat actually taken out for a large ingot.

The bed of the furnace was cleaned of slag, which was pushed out through the tap hole, and leveled up with a covering of Berkshire sand previously dried in an oven. A charge of 1,500 pounds of Swedish pig iron was then put in, and five minutes later 9,500 pounds of charcoal wrought iron, previously heated to redness in a small furnace. The pig iron melted very quickly, and formed a bath in which the wrought iron gradually melted away. At intervals during the first hour following, scrap steel was introduced: 4,825 pounds of plate scrap, 8,100 pounds of hammer scrap, and 500 pounds of furnace scrap. The whole mass, subjected to great heat, became liquid in about three hours. At the end of four hours 1,550 pounds of Swedish pig iron was added, and about 75 pounds of limestone to aid the formation of the slag which rose to the surface. During the process the molten metal continued to boil and emit gas, being stirred or "rabbled" occasionally to mix it thoroughly. A test ingot, taken out in a small ladle and cast at the end of six hours, showed .14 per cent. of carbon by a rapid chemical analysis, and 1,500 pounds of wrought iron heated as before were added to bring the percentage of carbon down. Forty-five minutes later another test gave .11 per cent. of carbon; 960 pounds of wrought iron and 70

pounds of ferro-manganese were added to bring up the charge in weight. The last test, taken seven hours and twenty minutes from the beginning, gave .11 per cent. of carbon. Ten minutes later 470 pounds of ferro-manganese were placed at the door of the furnace and gradually shoved into the bath. This contained enough carbon to bring the percentage up to .20 per cent. The manganese acted as a solvent on the escaping gases, and the whole mass of molten metal became perfectly quiet. About ten minutes later the ladle was swung around under the tap hole and the metal run out.

Materials.	Time of charging.	Weight of charge, lbs.	Percentage by analysis.				Weight of iron.	Weight of carbon.	Weight of manganese.	Weight of phosphorus.	Miscellaneous.
			C.	Mn.	Ph.	Si.					
Swedish pig iron	6.55 A	1,500	4.5	.04	.01	.36	1,431.7	67.5	0.6	.2	.....
Wrought iron	7.00	9,500	.05	.....	.036	.....	9,491.8	4.8	.....	3.4	.....
Plate steel scrap	7.30	4,825	.14	.40	.04	.....	4,797.0	6.8	19.3	1.9	.....
Furnace steel scrap	7.35	500	.50	.75	.04	.....	493.5	2.5	3.8	.2	.....
Hammer steel scrap	7.45	8,100	.28	.54	.06	.....	8,028.7	22.7	43.7	4.9	.....
Swedish pig iron	11.	1,550	4.5	.04	.01	.....	1,479.4	69.8	0.6	.2	75
Limestone	12.	75	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	.....	26,050	.....	.....	.....	.....	25,722.1	174.1	68.0	10.8	75
At 1.15, test for carbon	.....	.....	.14	.....	.....	.....	.....	36.0	.....	.....	.....
Carbon lost	.....	.....	.....	.....	.....	.....	.....	138.1	.....	.....	.....
Wrought iron	1.30P	1,500	.05	.....	.036	.....	1,498.7	0.8	.....	0.5	.....
Total	.....	27,550	.....	.....	.....	.....	27,220.8	174.9	68.0	11.3	75
At 1.45, test for carbon	.....	.....	.11	.....	.....	.....	.....	29.9	.....	.....	.....
Carbon lost	.....	.....	.....	.....	.....	.....	.....	145.0	.....	.....	.....
Wrought iron	1.46P	960	.05	.....	.036	.....	959.1	.5	.....	.4	.....
Ferro manganese	1.48	70	5.3	80.	.....	.....	10 3	3.7	56.0	.....	.....
Total	.....	28,580	.....	.....	.....	.....	28,190.2	179 1	124.0	11.7	75
At 2.15, test for carbon	.....	.....	.11	.....	.....	.....	.....	31.0	.....	.....	.....
Carbon lost	.....	.....	.....	.....	.....	.....	.....	148.1	.....	.....	.....
Ferro-manganese	2.30	470	5.3	80.	.....	.....	69.1	24.9	376.0	.....	.....
Total	.....	29,050	.....	.....	.....	.....	28,259.3	204.0	500.0	11.7	75
Steel obtained from heat	.....	26,500	.24	.57	.042	.....	26,274.3	63.6	151.0	11.1	.....
Materials lost in slag and flame	.....	2,550	.....	.....	.....	.....	1,985.0	140.4	349.0	.6	75

The preceding table gives the time when every charge was

added, with an analysis of each one. It represents fairly well what actually took place in the furnace, although the materials that went to form the slag cannot be accurately given. The analyses for carbon were rapid, and probably not exact; but the results are correct enough to show the principle. The silicon and other impurities could not be obtained, but they were small in quantity, and have therefore been neglected.

Since 1,985 pounds of iron were lost during the process, the actual amount of iron at 2.15 p. m. was 26,205.2 with 28.8 pounds carbon. By adding ferro-manganese the iron and carbon became 26,274.3 and 53.7. The estimated carbon was therefore 20.4 per cent.

The time required for this heat was seven hours and forty-five minutes and the metal obtained about 91.2 per cent. of the charge placed on the hearth. A small ingot, taken out just before pouring, gave .24 per cent. carbon, .65 per cent. manganese and .039 per cent. phosphorus. Analyses from the two ends of the large ingot cast gave .19 per cent. carbon, .52 per cent. manganese, .032 per cent. phosphorus, from the lower end; .32 per cent. carbon, .63 per cent. manganese, .052 per cent. phosphorus, from the upper end, showing that the impurities tend to rise to the top.

The above metal was made for a forging and was poured into one large ingot, but the process for castings is the same with the exception of the ferro-manganese, which is replaced by some alloy of silicon, manganese and iron. The weight of wrought iron, cast iron and scrap are, of course, varied with the qualities of the metals desired, or the availability of supplies. In some cases ores rich in oxygen are added to reduce the carbon rapidly. It will be seen from the table that very little phosphorus burns out, and materials nearly free from this objectionable element must be used in the ordinary process.

Manganese and silicon burn out rapidly, or form a slag during the process, and the charge of ferro-manganese is added just before pouring to bring the steel to the desired chemical condition.

The charge for a number of machinery castings, including a

large piston, was Swedish pig iron, 4,030 pounds; spring steel scrap, 3,930 pounds; locomotive tires, 3,880 pounds; scrap steel, 3,640; Clipper Gap ore, 200 pounds; ferro-manganese, 90 pounds; and ferro-silicon, 418 pounds. The analysis of the resulting metal gave .23 per cent. carbon, .61 per cent. manganese, .243 per cent. silicon and .076 per cent. phosphorus.

In crucible casting the steel is made in crucibles prepared for the purpose, holding from 70 to 100 pounds. The carbon can not be burnt out as in the open hearth, and the mixture is made beforehand. It consists of various kinds of scrap, such as old rails, plates, springs, tires, wrought iron, pig iron, &c., with a small quantity of manganese or silicon added at the end. The scrap is broken up and mixed to produce the proper grade of steel. It is then placed in crucibles previously heated to redness in the furnace, and clay lids placed over them. The metal melts in a few hours, and its fluidity is tested with an iron rod. The "physic," ferro-manganese or silicon, is then added to get rid of the gases, and the pots allowed to stand half an hour before pouring into the moulds. These pots can be used several times, and they are usually replaced on the fires immediately after pouring.

This process is difficult, but with careful supervision and close attention to detail, excellent results have been obtained. It is sometimes applied to castings where much pig iron is mixed with the steel scrap. A metal approximating to white cast iron is produced, easily melted and poured, but very hard. Such castings must be thoroughly annealed in some decarbonizing agent before anything can be done with them. They are the so-called malleable iron.

The Bessemer process has not been successfully employed for machinery castings.

Moulding for steel is very similar to that for cast iron, the main difference being due to the higher melting point of the former, and its rapid solidification, the great shrinkage and the gases developed in cooling. The body of the mould for large castings is made of ordinary moulding sand packed a little harder than for iron, with a facing of quartz ground very fine and damp-

ened with clay wash to give it a body (or mixed with a small quantity of clay and dampened with water). This facing is put on from 1½ to 2 inches thick, depending on the weight of the metal. For moderate sized castings ground quartz is used without moulding sand. Ordinary beach sand is used for a parting. After removing the pattern a wash of finely pulverized silica or Berkshire sand mixed with water is put on, and the mould afterwards washed over with molasses water. Cores are made of the same materials.

The mould is thoroughly dried in a furnace of about the same temperature as for iron. This part of the process is very important, as the least bit of moisture is almost certain to spoil the casting. The best results are obtained with slow drying. A mould for an eighty-five-inch piston required about three days in the oven.

The flasks are usually of wrought iron, or cast iron for unusual shapes.

The above is taken from the practice of the Pacific Rolling Mills, at San Francisco, where the castings are made from open hearth steel without subsequent annealing.

The following mixtures for facing are in use elsewhere:

Calcined fire clay, old crucibles ground fine and mixed with clay, quartz, sand, graphite and coal dust in various proportions.

Hard burnt fire clay ground fine and mixed with sugar or molasses water, as a binding material. This is used for the mitis castings, and resists without fusion a very high temperature.

Moulding compositions are also sold already mixed.

A wash composed of black lead mixed with clean China clay and water is used, sometimes the surface being well tarred.

The Pacific Rolling Mills have found a wash of crude petroleum to answer very well.

Light castings have been made in green sand.

To secure a good casting, careful provision must be made against gases and vapor, sand and other solid impurities and shrinkage.

1st. The mould must be thoroughly vented, and the metal poured in such a way as to carry in little or no air. When a

mould is filled the steel at once chills all around the surface, and "freezes in" the air bubbles or any gases given off in cooling. These would naturally rise to the top of a liquid metal, hence the necessity of large risers, which remain liquid long enough to feed the casting and collect gases and other impurities. These can afterwards be gotten rid of by cutting off the risers. Runners usually enter at the bottom of the mould, and the air or vapor can escape as the metal rises. By keeping the flow regular and the runners well filled the air is not carried in to a dangerous extent. A flaw, probably due to bad venting in connection with shrinkage, is shown in the cylinder head of figure 3, at *y*. This rim formed a pocket, and the air could not escape. One cut of the lathe exposed a hole extending entirely around the head.

In this connection, it may be well to state again that the ferro-manganese and silicon metal, "physic," as they are called in the mill, are added to get rid of the gases in the hot metal. Without them it would be impossible to secure a sound casting. Authorities do not agree as to the exact cause of blow-holes, giving variously carbonic oxide, hydrogen or air. Whatever the cause, manganese and silicon form a slag in the bath, which carries off much of the impurity and leaves the metal quiet enough to pour. The selection of materials for the steel is also important. In the example given in the table, the best charcoal wrought iron and pig iron, free from objectionable elements, were used.

2d. Sand and other solid impurities are gotten rid of by very careful attention to the mould. If the runner is not well baked and the sand thoroughly packed, the flow of metal cuts it out and carries it into the mould. Many castings have been lost from this cause.

The double crank disc shown in figure 4, and the reversing quadrant in figure 5, gave a great deal of trouble. Four or five of the crank discs were condemned on account of sand in the pin, and the first quadrant came out shapeless. The runner was finally thoroughly "nailed" and a wrought iron plate placed at the bottom of the vertical runner, *d*, for the metal to strike on. This got rid of part of the difficulty, but it was found necessary to cut away the mould over the journals of the quadrant at *s* to form

a pocket for sand, and to thicken the crank discs materially. The numerous cores added to the trouble.

3d. The shrinkage amounts to fully ¼ inch to the foot for soft steel and a little less for the hard varieties. This problem is probably the most difficult to deal with. A shrinkage crack can be found in almost every casting; and if not present, the metal is sure to have internal strains ready to show themselves at the first opportunity. Wherever a sudden change of shape occurs a crack is likely to appear.

Careful attention should be given to this question in the design. All angles should be well filleted, sudden changes of shape avoided, the cores eliminated as far as possible, and large masses of metal should merge very gradually into the thinner parts. As shown in figures 1 and 2, all the pistons cast have had cracks more or less pronounced in the fillet where the hub joins the disc, probably owing to the heavy mass in the hub.

In moulding, the cores should be constructed to yield readily to the shrinkage of the metal, particularly if cylindrical in shape, while they present a good strong surface. The use of cinders, as with iron, is found very satisfactory.

Cracks are often prevented by cutting ribs about ⅜ inch thick at the base and tapered off to nothing in the sand in the direction of the change of shape—that is, across all angles and projections. This is done with an ordinary chopping knife. These ribs chill quickly and bind the parts together, thus preventing change of shape. Many cases of this are shown in the figures at *f*. The cylinder head, figure 3, is a particularly good example. The projections were cut into the mould about ten inches long opposite the ribs.

Steel chills so quickly that it cannot be fed, like cast iron, from one or two small heads. For this reason a riser must be placed over every large section of metal. These risers should be from 18 inches to 3 feet high, depending on the size of the casting, with plenty of metal to remain liquid longer than the casting. In addition to feeding, they thus serve to exert a pressure on the metal and to fill all parts of the mould. They must be filleted off at the base into the body of the casting; never reduced

to a small neck if it can be avoided. This last is often done to save expense in cutting off, but it is questionable economy. These heads serve to fill in the shrinkage and to pocket most of the impurities and gases, as explained before.

As this subject is by far the most important in steel castings, a short explanation of the figures will probably give the clearest idea of the difficulties.

The risers are all lettered *c*, the runners *d*, *r*, shrinkage or feeding cracks *x*, blow holes *y*, and binding ribs cut into the mould *f*. Failures have been purposely selected for better illustration, not with any idea of condemning all steel castings.

Figure 1 shows a 60-inch piston cast with two heads on the hub and cored for the piston rod, the runner being divided into three branches which enter on the outer rim. It was condemned without turning up, for shrinkage holes at *x* and blow holes at *y*. It was next cast as shown in figure 2, with two risers at *a b* over the rim and cored in the hub. The runners entered the hub. This piston was condemned for holes at *z* in the hub, and cracks at *z* in the rim. A third trial with a very large riser over the hub, and no core, gave the best results, but slight cracks at *x* in the fillet made the case doubtful.

The cylinder head of figure 3 failed on account of cracks in the flange. These were probably caused by the flange solidifying and the centre drawing away from it in cooling. Two large risers had to be necked down on account of the shape of the head. This casting was finally obtained by filleting from the rim *y* down to the outer edge of the flange.

The quadrant in figure 5 failed on account of the crack at *x*.

The crosshead of figure 6 was condemned for cracks in the fillets of the wrist pins. This crosshead was cast with the large head as shown, and without cores for pins or piston rod. The pins were afterwards cored, as shown, to reduce the mass of metal, and no further failures from shrinkage cracks occurred, although several crossheads were condemned for sand in the journals.

The eccentrics were cast in the manner shown in figure 7.

Shrinkage cracks were found at x, when the bolt holes were bored.

The stern post in figures 8 and 9 was cast with heads over every heavy part and many little ribs were cut into the angles. The first large stern post cast at the Pacific Rolling Mills had several small cracks in the angles where the lugs join the vertical part of the post, not serious enough to condemn the casting, however.

The shaft strut in figure 10 was condemned on account of a crack in the fillet at x. It was cast with heads as shown.

In the above cases, most of the holes are inside of the metal, a few on the surface, but they are all due to shrinkage. They were caused by the metal chilling on the surface or in the thinner parts, and then drawing away in the heavier and hotter parts. Feeding cracks are very often found under the risers.

Shrinkage is said to be decreased by reducing the silicon and adding manganese, which lowers the melting point.

Occasionally the evil is averted by stripping portions of the casting soon after pouring.

The ladle is lined with fire brick or ganister, which is heated to redness by a gas flame before tapping the furnace. Every shop should be provided with machinery for handling the ladles quickly, so that there may be no delay in pouring. The metal must be quite liquid, and every precaution taken to prevent chilling. It is always poured from the bottom, by lifting a plug and allowing it to run into the mould. The time of pouring varies greatly. The runner should be made of such a size that it can be kept full without running the metal too slowly.

For an 85-inch piston, weighing in the rough 7,515 pounds, or 11,905 pounds including runners and risers, the mould was filled in 26 seconds through a runner 4 inches square. A stem weighing 11,470 pounds, or 19,540 pounds including heads and runners, was poured in 50 seconds through a runner 5 inches square.

The mechanical qualities of the castings depend upon the chemical constituents. The strength increases with the carbon, but the ductility decreases, and steel very high in carbon has

little extension. Silicon is said to harden the metal, and in some cases to decrease the tensile strength. In larger quantities than .5 per cent. it decreases ductility very much.

Manganese increases the strength by removing the gases and impurities, and allowing the mass to become more compact.

Phosphorus renders the metal brittle and liable to crack. It seems to collect only in spots which afterwards develop unaccountable cracks.

No reliable data can be given to show precisely how the tensile strength and elongation vary with the above elements. The ordinary proportions for the different classes of castings are:

Hard steel castings,	C=.60 to .90 pr ct.,	Si=.35 to .45 pr ct.,	Mn=.60 to .80 pr ct.
Medium "	C=.35 to .60 pr ct.,	Si=.30 to .40 pr ct.,	Mn=.50 to .80 pr ct.
Soft "	C=.25 to .35 pr ct.,	Si=.25 to .30 pr ct.,	Mn=.50 to .80 pr ct.

The first grade is suitable for stamps, anvil blocks, &c. When annealed it has a tensile strength of 40 to 50 tons per square inch, with small ductility. These hard castings are made in great numbers by the Pacific Rolling Mills for mining work, cable roads, &c. They are gradually replacing cast iron for all parts where the wear is great. Medium castings are adapted to ordinary purposes. They have a tensile strength of about 34 tons with good extension, and test pieces bend well without breaking. They can be turned and bored easily. Soft steel castings are the most difficult to obtain of uniform quality. They have a tensile strength of about 30 tons with an extension of 10 per cent. to 20 per cent. in 8 inches. These castings often appear very rough on the surface, sometimes with many blow holes, but are fairly reliable notwithstanding. Roughness is often an indication of mildness and ductility.

In the examination of castings the serious defects seldom develop until the skin is taken off. This adds much to the expense of obtaining steel castings where there are many failures. The method of suspending and sounding with a hammer tells very little, if anything, about the interior. Some of the worst castings have the clearest ring and the best surfaces. As a rule the large castings with fairly regular sections are sound, but those for

machinery, especially if they have many cores and angles, must be regarded with suspicion.

The piston in figure 2 appeared perfectly sound until turned up, and the two holes in the hub did not seem serious even then. The connection between these two small holes, which were about one foot apart, was shown by pouring water into one until it ran out of the other. About one quart being required to fill the cavity. The crack around the flange of the cylinder head, discovered only after the head had been turned up, held at least a quart.

On the other hand, defects which appear very serious are often only in the surface. The crosshead condemned for a crack in the fillet of the pin, after having been turned up, was broken by a drop. It was supported at the ends of the pins, which were 7½ inches diameter by 8 inches long, on two heavy pieces of steel about 2 feet apart, and a weight of 5,200 pounds dropped 16 feet upon the centre.[1] After several blows one of the pins broke in the fillet, the fracture being clean and free from blow holes. The crack did not extend ¼ inch below the surface.

A 28-inch piston, which showed small holes in the hub, was broken under the steam hammer. The fracture exposed a large cavity starting with these holes and extending down into the disc almost entirely through the piston, the actual thickness of metal being only one-third of that required.

The above cases are cited only to show the uncertainty of surface inspection before machining.

Pieces have been successfully welded into some cracks well located for that purpose and the castings perfectly restored.

The expense of manufacture is greatly increased by the removal of heads and runners. The heads are necessarily large in most cases, and they have to be drilled or slotted off, and the surface chipped to conformity with the adjacent parts of the casting. This involves many days of labor where the heads are in bad locations for the machine, as on a stern post. A portable drill with rope gearing is the best tool for this purpose.

The following table will give some idea of the relative weights of castings and parts afterwards cut off:

	Weight of casting.	Weight of risers.	Weight of runners.	Total Weight.
Stem	11,470	8,070		19,540
Hawse pipe	3,080	560	268	3,908
85″ piston	7,515	2,820	1,570	11,905
Stern post	11,510	7,550	1,885	20,945
Stem	14,590	8,285	1,622	24,497
Shaft strut	12,370	3,530	710	16,610
Rudder frame	13,550	3,665	1,200	18,415

The ship castings being generally large and without finish can be made nearly to size, but many of the machinery castings lose greatly in the machine shop, and the work of removing the metal is very great.

A few examples are given of the amount taken off.

	Rough weight.	Finished weight.	Loss of weight.	Percentage of loss.	Remarks.
	lbs.	*lbs.*	*lbs.*		
44″ piston	2,656	1,545	1,111	41.8	Finished all over.
85″ piston	7,515	4,425	3,090	41.1	Finished all over.
28″ piston	640	274	366	57.2	Finished all over.
Main eccentrics	556	285	271	48.7	Finished all over.
Reversing quadrant	970	757	213	21.1	Finished in journals, faced on the arms.
Crosshead	1,317	943	374	28.4	Finished on journals and bottom, and bored for piston rod.
Double crank disc	647	376	271	41.9	Finished on surfaces.
H. P. air-pump piston	98	56	42	42.9	Finished all over.
L. P. air-pump piston	190	112	78	41.1	Finished all over.
Manhole covers	220	154	66	30.	Finished on outside.
42″ piston	1,310	1,020	290	22.1	Partly finished.
42 cylinder heads	1,410	1,145	265	19.1	Finished on flanges.
Stern post	11,510	10,966	544	4.73	Rivet holes drilled.
Stem	14,590	14,450	140	.96	Rivet holes drilled.
Shaft strut	12,370	11,680	690	5.58	Bored for stern tube.
Rudder frame	13,550	13,365	185	1.37	Rivet holes drilled.

The first four of the above castings were made under a misunderstanding about the finish, and show a greater loss of weight than necessary; but at best the average loss cannot be less than from 20 to 30 per cent. of the weight in the rough.

The gain in the use of steel castings is not always in proportion to the cost. When lightness is the chief requisite, as in the reciprocating parts of a high speed engine, this does not enter into the question; also where the chief aim is reduction of weight.

In some cases, however, their adoption adds only to the expense. The crank discs of figure 4 are an instance in point. These discs were very expensive to the steel mill on account of many rejections, and the cost in the machine shop was excessive. A rough comparison is given of the cost of a double crank shaft in one forging, and cast iron discs slipped over the cranks, with the shaft as actually fitted:

1 forged steel double crank shaft (finished),	470 lbs., at 35 cts.	$164 50
4 cast iron discs (turned and fitted),	562 lbs., at 14 cts.	78 50
Total	1,032 lbs	243 00

As fitted—

3 lengths of forged steel shafting (finished),	280 lbs., at 18 cts.	$50 00
2 cast steel double discs and pins (finished and fitted),	752 lbs., at 60 cts.	451 00
Total	1,032 lbs	501 00

The price as fitted is the actual cost of this work in the shop, and it does not include the work on rejected materials. There is neither gain of weight nor strength in this case; besides, the shaft has only a small amount of work to do.

In the matter of large cylinder heads, where the steel cannot be cast much under the dimensions required for cast iron, its adoption again increases expense without adding much, if anything, to safety.

There is room for much judgment in putting cast steel into the parts of an engine. While it is admirable for hull work, and serves a good purpose about machinery, it seems unwise to adopt it indiscriminately, or even to adopt it at all unless there is decided and unquestioned gain.

The advantage of annealing is becoming more apparent. It improves the metal by rendering the texture more uniform, and removing internal strains, which undoubtedly exist in all castings. The ductility is increased and the tensile strength slightly decreased.

The process consists in placing the casting in a gas oven nearly cold, and gradually bringing it to a cherry red heat, then allowing it to cool slowly in the oven.

Castings high in carbon may be made quite soft by heating them in contact with iron ore or some decarbonizing agent.

At Terrenoire a system of tempering in oil has been adopted, which is said to be equal to forging.

There is no difficulty in obtaining castings to satisfy the Department requirements for tensile and bending tests, although the heads are frequently so porous as to make it hard to find sound test pieces.

A table of tensile tests and chemical analyses is subjoined for general information. The elastic limit cannot be obtained with accuracy, as with forged steel, and it should not be relied upon.

	Diameter, inches.	Area, sq. inches.	Length of piece.	Tensile strength per sq. inch.	Elastic limit per sq. inch.	Extension, pr. ct.	Reduction of area, per cent.	Analysis.			
								C.	Mn.	Si.	P.
			in.								
Rudder frame	.951	.7103	8	61,810	39,420	14.37	18.20	.24	.52	.354	.042
Rudder frame	.876	.6026	8	63,060	39,660	16.00	19.70	.24	.52	.354	.042
Shaft strut	.892	.6249	8	60,170	38,820	15.00	15.80	.225	.50	.256	.049
Shaft strut	.940	.6940	8	60,520	38,620	10.37	14.80	.225	.50	.256	.049
Stem splice	.880	.6082	8	71,250	35,800	23.25	27.30	.29	.59	.345	.052
Stem splice	.887	.6179	8	66,350	33,980	11.00	18.60	.29	.59	.345	.052
Stem—runner	.989	.7682	8	62,080	33,190	15.25	21.70	.25	.57	.324	.055
Stem—runner	.994	.7760	8	62,370	33,500	20.75	42.50	.25	.57	.324	.055
Stern post—runner	1.005	.7934	8	63,020	34,030	19.00	17.80	.25	.57	.315	.041
Stern post—runner	1.005	.7934	8	63,020	35,040	22.50	23.30	.25	.57	.315	.041
Stern post—head	.998	.7823	8	61,870	33,490	14.50	16.80	.25	.57	.315	.041
Stern post—head	.977	.7497	8	64,540	32,410	16.12	20.70	.25	.57	.315	.041
85-inch piston head	.940	.6940	8	63,400	33,140	13.80	12.30	.23	.61	.243	.076
85-inch piston head	.938	.6910	8	62,520	33,000	11.20	11.70	.23	.61	.243	.076
Stern—runner	.803	.5064	8	64,370	44,630	18.12	18.50	.26	.56	.259	.058
Stern—runner	.805	.5089	8	64,060	45,020	13.12	12.70	.26	.56	.259	.058
Stern—head	.813	.5191	8	61,140	43,920	14.00	17.10	.26	.56	.259	.058
Stern—head	.887	.6179	8	61,170	43,370	13.00	13.00	.26	.56	.259	.058
Crosshead	.867	.5904	3.4	64,020	36,750	23.80	28.10				
Crosshead	.867	.5904	3.4	64,530	37,260	16.50	19.10				
Miscellaneous	.539	.228	8	74,500	47,000	18.60	13.90				
Miscellaneous	1.007	.796	8	61,930	49,300	11.70	11.40				
Miscellaneous	.776	.473	8	69,590	33,000	12.00	13.90				
Miscellaneous	.876	.602	8	62,600	37,800	14.60	15.60				
Miscellaneous	.869	.593	8	65,400	38,800	20.10	24.30				
Miscellaneous	.832	.544	8	68,070	36,900	21.30	34.60				
Miscellaneous	.745	.436	8	73,100	31,800	8.25	8.10				
Miscellaneous	.730	.4185	8	69,300	29,000	12.30	8.50				

Much of the information given in this paper has been obtained through the courtesy and liberality of Mr. Noble, Superintendent of the Pacific Rolling Mills, and his assistants.

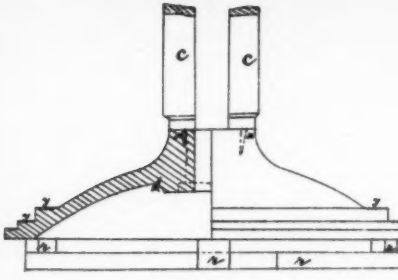
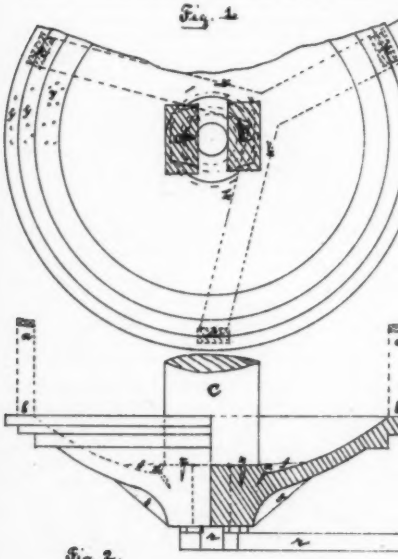


Fig. 1.



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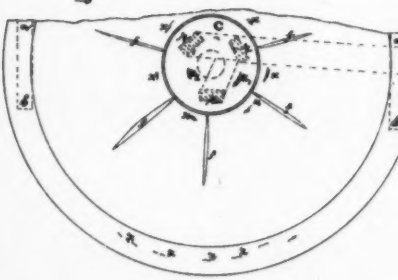

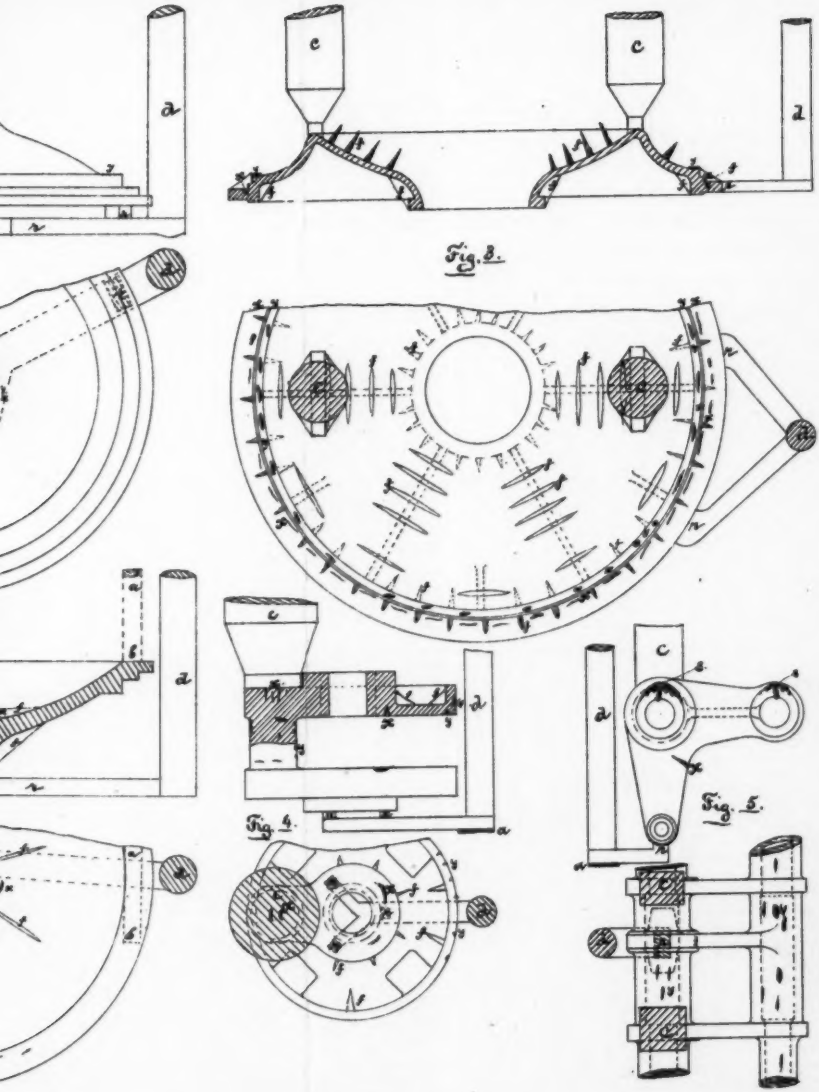
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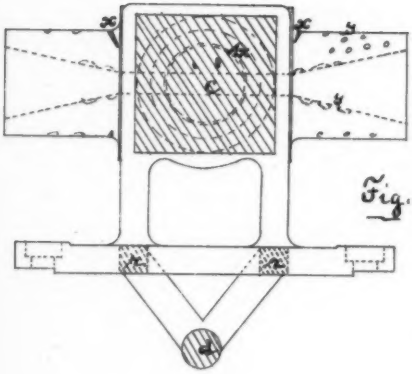
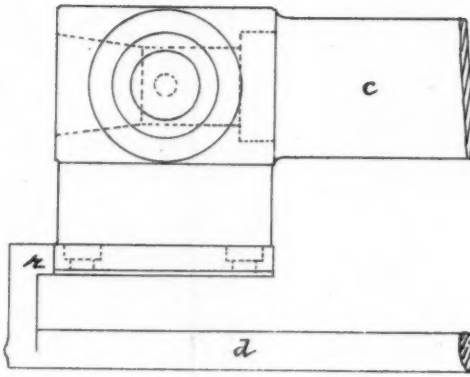


Fig. 6.



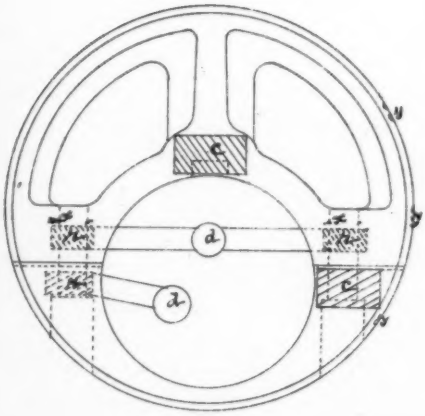
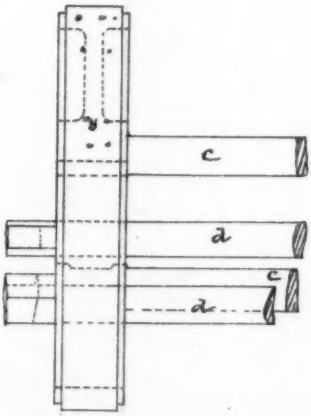


Fig 7.



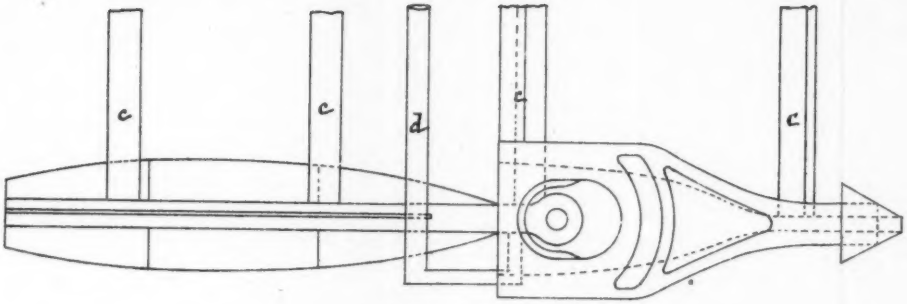
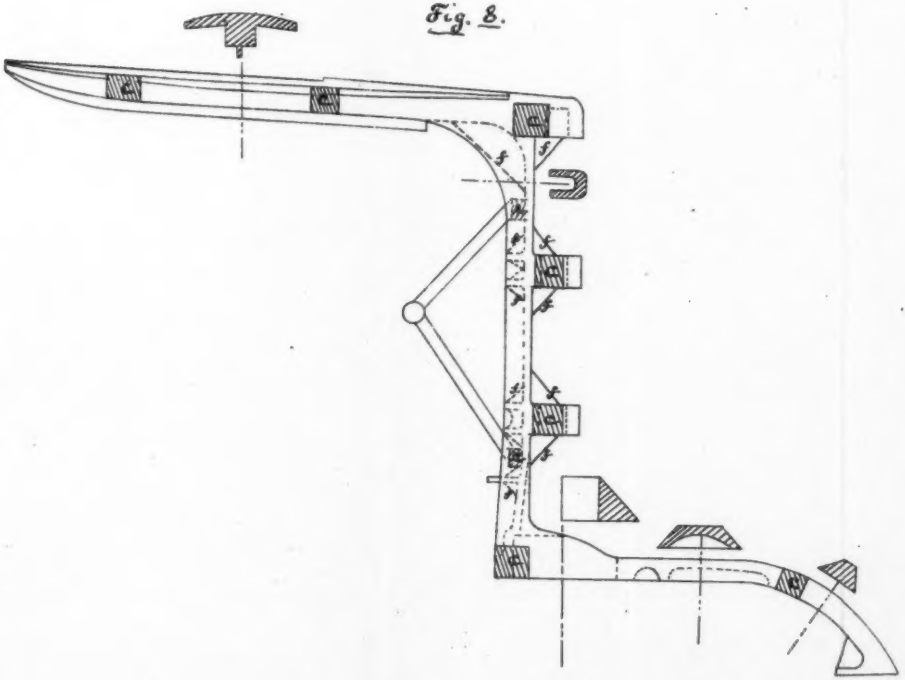
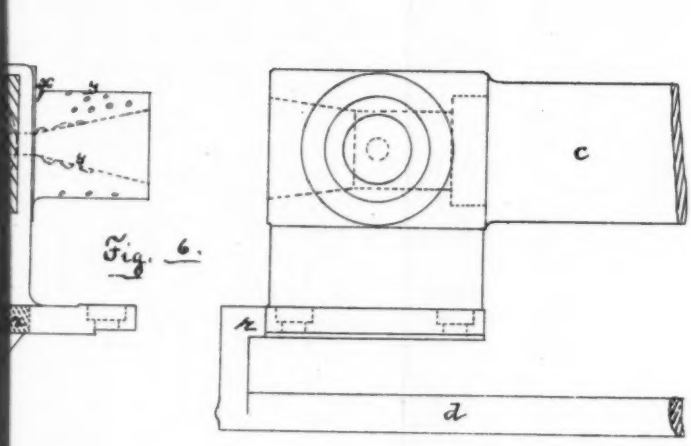


Fig. 8.





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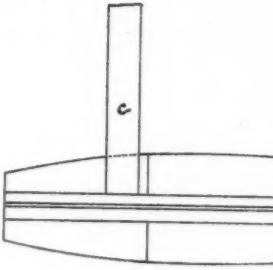

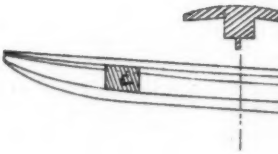

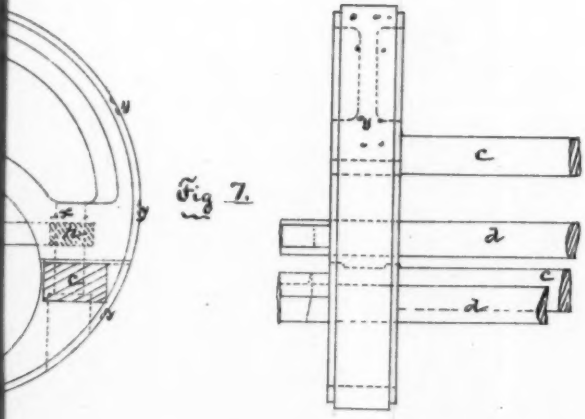

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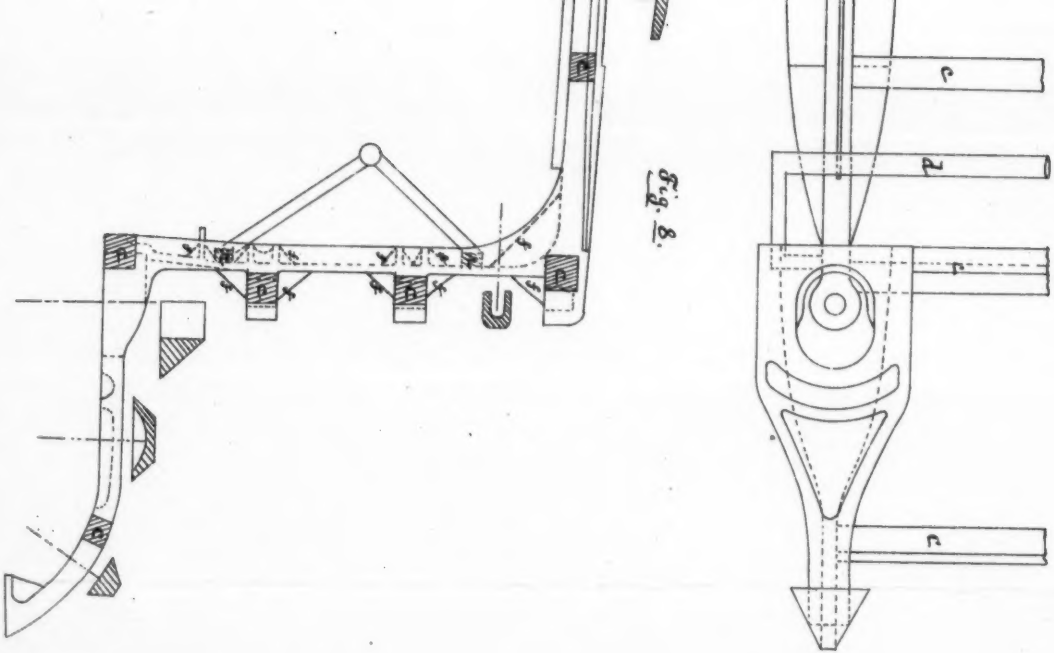

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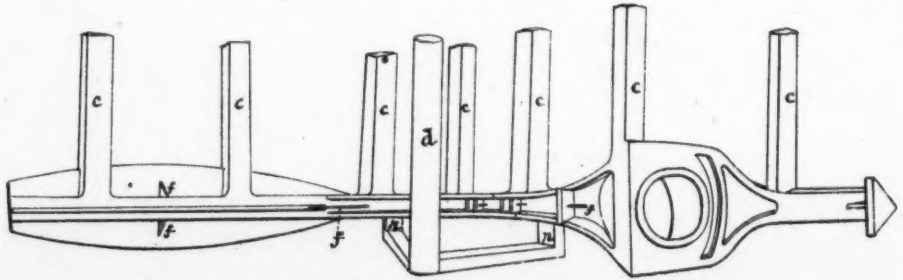

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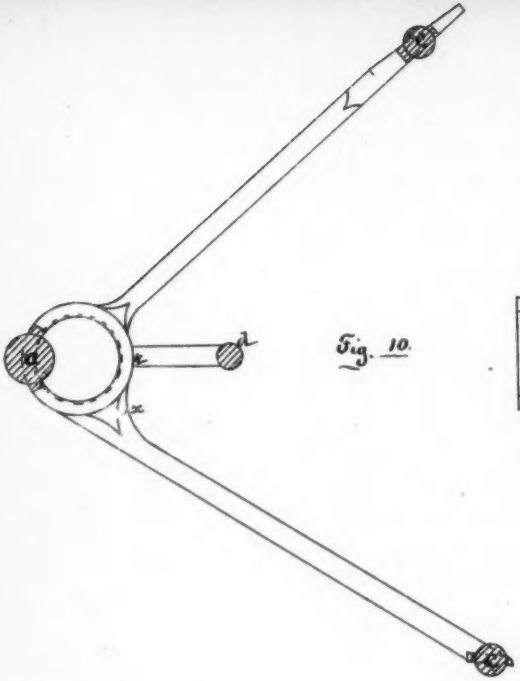

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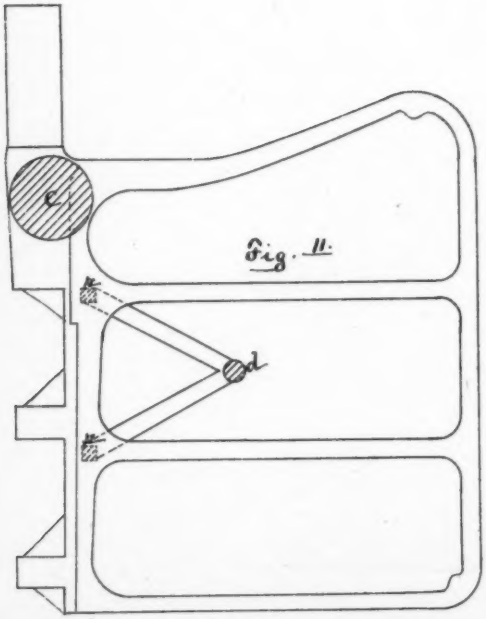

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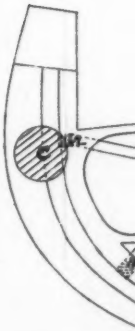
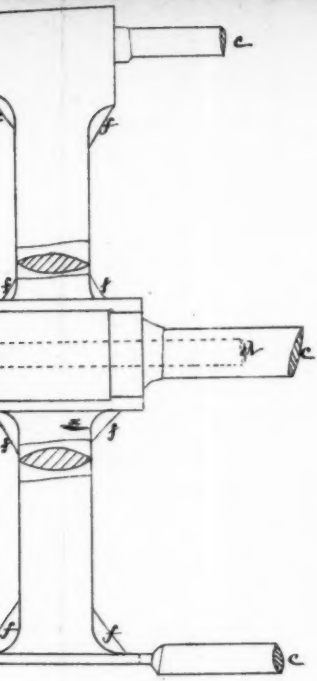
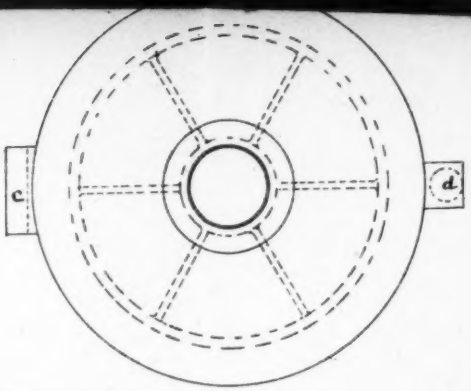






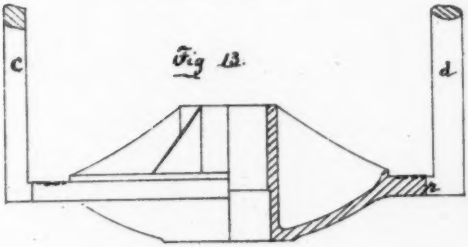
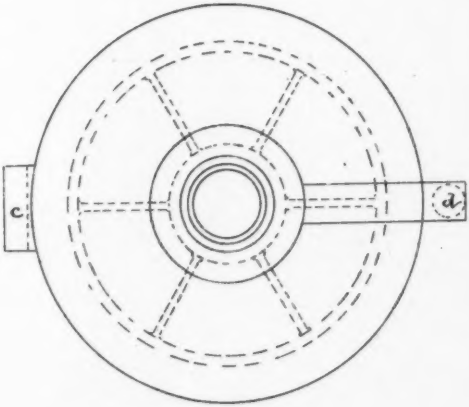


Fig 13.



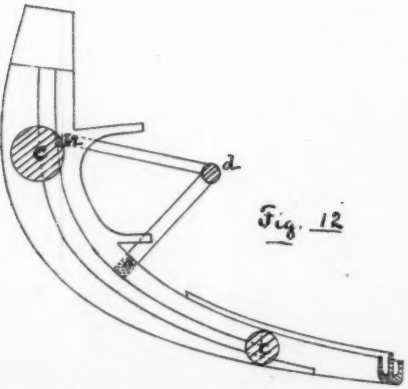
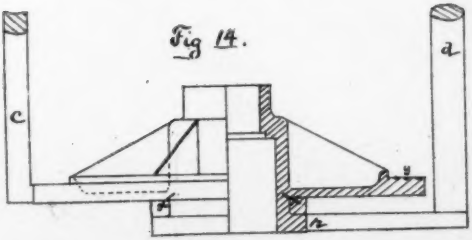


Fig. 12

Fig 14.



XV.

SPIRALLY WELDED TUBES.

By Mr. W. S. Aldrich, Member.

[Abstract from a paper read before the Philadelphia Branch, Feb. 27, 1889, Chief Engineer L. W. Robinson, U. S. N., in the chair.]

The object of the paper is to present a new process and invention in practical engineering before the Society. It contains a brief account of the labor of others in this particular field, and has been thought a matter of general interest to the engineering profession.

The making of spirally welded tubing is an entirely new industry. There is no precedent, and practically no literature on the subject. Spiral riveting has been tried in England on cylindrical boiler shells. The spiral joint is practically and theoretically the strongest for riveted or welded work. Increase of pressure but tends to bring the two pieces into close contact. This has been shown by a spirally welded tube leaking at 20 pounds pressure per square inch and tight at 100 pounds. In fact a tight joint is possible on the principle of the spiral seam, without any riveting or welding, provided the material is such that increase of pressure brings the two pieces into closer contact.

The material is used in form of ribbons of standard widths—6, 12, 18 and 24 inches. It is the ordinary sheet iron or steel of commerce. The ends of the ribbons are united by welding in the spiral welding machine, the strips are clamped for about ½-inch lap, the reel holding the ribbon is put in position, and one end of the strip is placed on the guide table. This is set at the angle due to the width of the strip and diameter of pipe. The strip is then carried into the machine by feed rolls, geared together, thence into the forming jaws, which bend it to the desired curvature, and is brought to a welding heat by a gas

furnace. It is held in place by a pipe mould, a cylindrical shell within which the pipe rotates as fed in, and welded by a hammer striking 160 blows per minute. The tube is supported by brackets as it leaves the machine.

The bursting strength of spirally welded tubes is very high, in comparison with the weight of the material used. A 4-inch pipe, weighing 2.06 lbs. per lineal foot, has a proof strength of 980 lbs., and an ultimate strength of 1593 per square inch. A lap welded iron pipe, of the same diameter, weighs 10.72 lbs. per linear foot, and a cast iron pipe ½-inch thick weighs 22.05 lbs. A 24-inch spirally welded pipe, weighing 16.40 lbs. per linear foot, has a proof strength of 216 lbs. per square inch, and an ultimate strength of 352 lbs. per square inch.

I have no data at hand on the bursting strength of copper pipe. A 4-inch copper pipe $\frac{1}{32}$-inch thick weighs 1.73 lbs. per linear foot, and $\frac{29}{64}$-inch thick weighs 24.6 lbs. A 24-inch copper pipe $\frac{1}{32}$-inch thick weighs 10.2 lbs. per linear foot, and $\frac{29}{64}$-inch thick 134.8 lbs.

The applications of spirally welded tubes are many. They find ready use in any branch of steam engineering, land or marine, especially for steam pipes, heaters, superstructures, &c., and in any service requiring pressure pipes of great strength, lightness and durability.

Couplings, joints, bends, etc., of light castings are easily applied to spirally welded tubes. They have not so far been themselves bent or curved, or otherwise used out of a straight piece.

[In 1887, an exhaustive series of tests was carried out by Mr. Nesbit Sinclair, at the works of Messrs. Napier & Sons, Glasgow, to determine the strength of brazed copper pipes when heated to the temperatures obtaining with high pressure steam. The tests were made at temperatures of 55, 330 and 370 degrees Fahrenheit, the specimens being taken across the joint as well as clear of it. The tensile strength across the joint varied from 8.59 to 12.32 tons; clear of it, from 10.19 to 13 tons. The general conclusion drawn from the tests was that the strength of ordinary copper pipes should not be taken at more than 60 per cent. of the strength of the copper from which the pipe is made.—Ed.]

XVI.

SOME LESSONS FROM SAMOA.

By Chief Engineer F. G. McKean, U. S. Navy.

1. Among these the most important is the necessity for increased power. If our ships had had power approaching that of the *Calliope*, some of them at least might have "clawed off" as she did. Her escape is one of which marine engineers may well be proud, and we may congratulate ourselves that our new vessels will do fully as well in any future similar contingency.

2. Protection to propellers would seem at first sight a lesson to be learned, and it might be considered even more necessary with twin screws than with single propellers, since the former are placed at some distance from the center line of the hull, and are more exposed to wreckage, though incidentally, they protect the rudder more effectually. The screw could be protected to some extent by a revival of the old cage; but the latter, to be adequate to the purpose intended, would cause resistance to the progress of the ship, while if weak, it would add to the risk, since wreckage might batter and bend it so as to cause the very obstruction which it is wished to avoid. Perhaps we will have to console ourselves with the hope that only one screw is likely to be disabled, and that the other will serve in an emergency.

3. It would appear that smoke-pipes can be made secure against wind, but that they are not always proof against collision. In old times it was thought that the great danger was from a smoke-pipe being so flattened or bent over that the gases might drive every one from below before the pipe could be cut away. There seems to be some ground for this fear, because, on the *Nipsic*, after matters had quieted down, the closed lips of the standing part of the smoke-pipe had to be opened before steam was raised to pump out the ship. The steady decline of steam

in the interval between the collision and the beaching of the vessel would probably have been much slower had it not been for the closing of the pipe, while the shortness of that time was perhaps all that prevented the accumulation of the gases from seriously affecting those who were below. Every engineer will make up his mind what means are available in similar circumstances,—whether tackles can be hooked on the edges of the pipe to pull them apart, while handspikes and sledges or screw-jacks assist in the process,—and he should consider how they can be worked in an emergency while smoke is still escaping and the parts are hot. The *Nipsic's* experience would indicate the necessity for commanding very strong artificial draft, and we have reason to expect that our new ships will not be deficient in this particular.

4. The fact that the *Calliope* barely escaped at the rate of about one-half knot per hour, has led some engineers to attribute her success to the fact that her propeller was made of manganese bronze; its slightly greater thinness, lightness, smoothness and truth over the old screw of ordinary composition of the same dimensions being sufficient to account for the difference in speed. As our new screws are of manganese bronze, we will reap these benefits. It is true that Captain Kane is said to ascribe the excellent performance of the *Calliope* on this occasion to the use of a certain coal (Westport), but it has been doubted whether any Australian coal is 25 per cent. superior to English Newcastle, as was claimed for this.

5. The great advantages of having bilge strainers perfectly accessible should not be overlooked; also the prudence of starting pumps and the bilge injection before the depth of water becomes so great that men cannot easily keep the strainers clear, and cannot by actually feeling the holes perceive whether, for instance, the circulating pump is drawing water out of the bilge or whether water is flowing back into the ship from the sea. When, however, the bunkers are torn away from the hull, it would seem difficult to keep coal away from the strainers unless these were duplicated — that is, in compartments which were themselves, to some extent, strainers.

Some other lessons which might be learned from last March do not appertain so much to naval engineering proper, though they might be of vital importance to the personnel of that branch. Among them are:

6. The advisability of having at least one rocket apparatus or life-saving gun, capable of being moved to any part of the spar deck, always ready for use, and with a couple of spare projectiles and lines, in case the first should miscarry or should need to be supplemented. Both the *Trenton* and *Vandalia* might have profited by the possession of such an apparatus, which would also be "a handy thing to have" even in the case of an ordinary collision, or for passing a tow-line in bad weather, etc.

7. The life preservers were stowed below and could not be reached in sufficient numbers for the whole crew of at least one of the ships. Perhaps a couple of receptacles on the spar deck, one forward and the other aft, could be usefully fitted up for these articles so contemptuously spurned in fair weather, or the allowance for the crew might be stowed between the beams overhead in places accessible to all at a moment's notice.

8. With water suddenly rising in the holds—and this might be expected in many collisions apart from those occurring in a gale—provisions could not be reached; and at Apia men are stated to have been for the greater part of two days with nothing to eat, insomuch that they were too weak to hold on. It would perhaps not be impossible to have some concentrated ration in small bulk, sufficient for one round, stowed in lockers forward and aft; and in case of abandoning ship from any cause this supply could be available for the boats.

9. The proposition of having men exercised in diving with the aid of the suit or other apparatus is an excellent one, for, apart from the convenience of being able to raise articles from wrecks, the armor would often be of great service in clearing fouled propellers, closing discharge orifices temporarily for repairs, examining copper after touching ground, cleaning the bottom, etc. The scheme appears to be a revival, for one of our flagships in the Mediterranean squadron had a complete French outfit of air-pumps, suit, etc., more than twenty years ago.

10. The advisability of cutting away the masts need not be touched upon here, as it has received notice in other quarters; and if it had been carried out in this instance the *Vandalia's* people would have been poorly off indeed.

11. The position of hawse-pipes will no doubt receive due attention in our new ships, though in them the water-tight bulkheads should at least prevent the fires from being extinguished under all the boilers.

DISCUSSION.

PASSED ASSISTANT ENGINEER HERSCHEL MAIN, U. S. N.—To the lessons drawn from the Samoan disaster by Chief Engineer McKean, I will only add a few illustrations and observations drawn from my experience as a participant.

The necessity for more power would seem, at first thought, to especially apply to the *Trenton*, as she was anchored in the outer harbor, and was in a more convenient position for getting to sea than the other ships; but, had her steam power been double what it was, she could not have got out, as the loss of her rudder early in the morning rendered escape impossible. After this, any quantity of steam was available merely for easing the pull on the chains.

As the *Nipsic* and the German steamer *Adler* each lost her rudder, while the screws of all the ships remained intact or were only slightly injured, it would seem that an improved form of rudder, and a more efficient method of securing it, is of greater necessity than protection for the propellers. The one great danger to which a propeller is peculiarly exposed is that of fouling by ropes, etc. There was an instance of this on the *Vandalia*, the clearing of which was the occasion of a striking display of courage by one of the crew.

The Westport coal referred to in connection with the escape of the *Calliope* is a product of New Zealand. I have not had any experience with it, but from the terms in which it is invariably spoken of by English engineers and others, I am satisfied that it is fairly superior as steaming coal to the best Newcastle, and not much, if at all, overrated by Captain Kane.

The necessity of having bilge pumps and strainers accessible was especially impressed upon me in my experience on the *Trenton*. Besides two 8-inch plunger pumps attached to the engine, she had two Blake pumps with 12-inch water cylinders, a small Blake pump used for pumping bilge in port, and a steam ejector with a 3½-inch discharge pipe, all available for pumping water out of the ship. With the exception of the ejector, which had a strainer of its own, the suction pipes of all the pumps were provided with Macomb strainers, each of which, except that of the small Blake pump, was placed below the floor plates and in a position awkward to reach. The strainers of the bilge injection pipes were still less accessible. They were of box shape, and made of pewter plates pierced with holes. To reach them it was necessary to pry up a large and heavy floor plate and crawl under another one. The bilge injection valves were ordinary disc valves placed near the sea injection valves.

The circulating pumps were of the centrifugal type. It is well known that such pumps cannot, without being first primed, be counted on to lift water, while in this case the lift was 3½ to 4 feet to take water from the bilge, and yet there was no special provision for priming the pump. On the other hand, there was an available method of priming by having the pumps, in the first place, at work from the sea, and then starting the bilge injection before the sea injection was fully closed, shutting the latter tightly as soon as the pump commenced to draw from the bilge. I have been reliably informed that centrifugal pumps identical with those of the *Trenton* have, when first primed, lifted water continuously a height of over 20 feet.

On the morning of the disaster a quantity of beans was left on the berth deck, and the flood of water entering by the hawse holes, washed them and other refuse aft and into the bilge by way of the orlop-deck hatch. From this cause, the machinist of the morning watch had all he could do, with the assistance of another man, to keep the strainers clear. Either from an increased quantity of water pouring down the hatches and from the berth deck, or from other causes, the water in the bilge afterwards began to increase rapidly, and then the disadvantage

of strainers located as ours were was apparent. This was intensified when the water got high enough to wash down the fine coal and refuse from the fire-room floor into the strainers of the Blake pumps.

Bilge strainers should be placed as near as possible to the suction end of the pipe, as it is sometimes a tedious job to remove a chunk of waste or a piece of an old shirt from out a long length of pipe, and they should be well above the floor plates.

The steam ejector should have been a powerful auxiliary on the bilge, but its strainer was so located that it could not begin to work until there was nearly 20 inches of water in the bilge. Its steam valves were reached and operated from the berth deck, which at this time had over a foot of water on it, rendering the opening of these valves no easy matter. When they were opened, so great was the volume of water coming into the ship that the fires were about extinguished, and it was deemed more economical to use what steam was left on the auxiliary pumps.

I think few commanding or executive officers would agree with Chief Engineer McKean as to stowing life preservers in easy reach. In the first place, it would be looked upon as assisting desertion, and in case of emergency as having a demoralizing effect by detracting from the singleness of effort on the part of the crew to save the ship as their *one* hope of safety. But on one point all must agree, viz., that the quality of the life preservers provided should be reliable. The *Trenton* had been supplied with a poor quality of the absurd granulated cork variety, most of which had been condemned and got rid of some time previously. I think there were less than a dozen left on board.

I consider lesson 8 a valuable suggestion, and am able, from a previous experience, to offer a striking illustration of its importance. Upon the occasion of the wreck of the *Saginaw*, in provisioning the boat which we sent forth to seek relief, we were able to give them, among other things, a few cases of desiccated potatoes. All the other provisions in the boat were soon spoiled by salt water, or rendered useless from lack of means to cook it, and for a great part of their weary journey of over 1,500 miles of

ocean their one dependence was these few tins of desiccated potatoes.

There was a good diving apparatus on the *Trenton*, and two fairly expert divers accustomed to its use. It was in constant use subsequently to the wreck, and we had a regular diving boat party at work nearly every day.

CHIEF ENGINEER N. P. TOWNE, U. S. N.—In addition to the suggestions made in regard to the pumping service of ships, it has often occurred to me that in case of a heavy leak there would be a great source of danger between the Macomb strainer and the bilge from the long pipe, as usually fitted, becoming clogged with waste or other material. I think that, by making this pipe with a cap fitted in a similar manner to that on the strainer, it could be easily cleaned by pulling the obstructing substance up with a screw rod or punching it down, this cap being well above the floor and in an open part of the engine room.

In wrecking pumps the suction pipes should not reach lower than within 10 or 12 inches of the skin of the ship; but in small pumps they might be let into a well, as they ordinarily are, which could be easily got at.

In locating bilge injection pipes, the circumstances under which they are to be used are not usually considered. The idea used to obtain that they should be placed at the lowest part of the bilge, and that object was attained by putting them under the crank. In such a case the engine would, of course, have to be stopped to reach the strainer, and the result in a ship without independent circulating pumps can be easily imagined.

Bilge strainers should be of good size, to avoid frequent removal, and duplicate baskets should always be provided to be put in place while the others are being cleaned, a matter of no little time when pieces of wood become so tightly jammed in them as to require cutting out.

A strainer basket should be 1½ times the diameter of the suction pipe and two diameters long. In one of our new ships the Macomb strainers were so small as to require the whole time of one man to keep them clean.

MR. WILLIAM COWLES, Member.—In reading "*Some Lessons*

from Samoa," I find matter which must appeal very strongly to every designing and constructing engineer engaged in marine work.

(1.) The principal problem in the naval design of to-day is how to increase "emergency power" without increasing weight and space occupied. I think this may be fairly assumed to outrank in importance any other question relating to war ships. There seems to be no way to solve this problem except through the use of water-tube boilers. Some engineers have been making a special study of this matter for years, and many of the best and most experienced among them have entirely abandoned the idea of adequately increasing the power of a vessel by using any type of cylindrical, fire tubular boiler. There must be a radical departure in the boilers before much progress can be made in this matter. The repeated failures of different types of "tubulous" boilers when used for extended periods under forced draft or from other causes, have, in my opinion, resulted solely from bad design.

These many failures have caused numbers of good engineers to hold a prejudice against any and every form of water-tube boiler; it is nevertheless a fact that our only hope of greatly increased power on shipboard lies in this type of boiler. A very vital feature of "emergency power" is the rapidity of generating it. Power which cannot be obtained quickly is not "emergency power" in any naval sense.

(2.) It does not seem practicable to make any permanent and fixed guard or cage for a propeller. If it is thought necessary to furnish some protection to a propeller it would seem as if it could best be done by strong and movable arms, guards or spars with heavy guys, swung or run out from the hull in time of need. Such an arrangement is, however, very likely to prove a useless "jim-crack" just when it is most needed. Experience in the use of a *swivelled screw* has proved that it can often be saved from fouling by simply swinging it over with the rudder.

(4.) I cannot regard the escape of the *Calliope* as due to any one excellence either in *personnel* or *materiel*. The result shows that she was a good all-round ship, well handled both on the

bridge and in the engine and fire rooms. The margin was so very narrow that a slight break or misjudgment anywhere would have wrecked her.

In the case of the *Trenton*, *Vandalia* and *Nipsic*, it was a plain matter of not enough steam. It was simply not possible for the boilers on these vessels to furnish the power to save them; the vessels did not have enough "emergency power" to save themselves; other smaller faults would and could have been overcome if the vessels had had a large "emergency power" in the boilers, but being hopelessly lacking in that vital thing, they had, of course, to go, and no amount of ingenuity, good management and bravery on the part of the *personnel* could save them.

(6 and 9). A small compact gun for throwing lines would certainly seem to be an important and useful addition to the equipment of every war ship; so also with the diving apparatus. In this connection it may be said that the immense amount of miscellaneous apparatus and equipment carried on a war ship is being increased every year, and the value of space, even to "nooks and crannies," is being enhanced accordingly. Every department on shipboard is crowded, and crying for more room, and trying to get it at the expense of others. The general design and lay-out of every new ship becomes therefore a battle between conflicting interests, which make up a more or less homogeneous whole. The very large and important saving in space resulting from the use of a suitable type of water-tube boiler could well be used in part to increase the coal capacity and endurance, and in part to relieve the cramped condition of the magazines and equipment store rooms, soon to be over-crowded still further by the increase in "rapid fire" ammunition, to say nothing of miscellaneous additions to the regulation equipment from year to year.

Personally, I am surprised, now that I am brought to think of it, and have to confess that in some five years of sea service on different naval vessels I do not remember being shipmates with a *visible* life preserver, except the two or four cork rings with lanyards which are carried on deck.

The life preservers must have been on board, because the regulations required it; but I do not remember ever having been

told where they were or how I might possess one without making out a requisition. Still, the spaces between beams and carlins were mostly vacant.

ASSISTANT ENGINEER EMIL THEISS, U. S. N.—As regards protection to the propeller by providing a cage for it to work in, Mr. McKean is right in saying that any advantage gained by securing the propeller against fouling would be balanced by the loss of speed due to increased resistance. This is true at least of the ordinary type of propeller. The Thornycroft screw turbine would be a superior contrivance in this regard. Twin screws are probably more liable to being fouled than single screws, though their exposed position, due to their distance from the center line of the ship is, to some extent, compensated for by their greater immersion. Besides affording protection to the rudder and relieving it of strain, twin screws may, in the event of the rudder being disabled, take its place.

The statement by Mr. Cowles on the superiority of coil boilers in an emergency needs qualification. If Mr. Cowles means that on introducing coil boilers into war ships the same weight of machinery is to be introduced as heretofore—or nearly the same weight—the power developed being increased over what could have been obtained on that weight with the type of boilers at present in vogue, he is right. But that is not the way the matter stands. Ships are designed, as a rule, to make a certain speed under given conditions, and the horse power is decided on accordingly. This being the maximum performance, is all that can ever be got out of the boilers and engines on that ship, irrespective of type.

ASSISTANT ENGINEER R. S. GRIFFIN, U. S. N.—I think it will be of interest to supplement Mr. McKean's paper with the size and engine power of some of the ships present at Samoa, and which I have prepared in tabular form.

It will be noticed that the I. H. P. per ton of displacement was 1.45 in the *Calliope*, 1.12 in the *Olga*, .62 in the *Trenton*, .55 in the *Vandalia*, and .61 in the *Nipsic*, and that the chances of escape were much more favorable for the *Calliope* than for any of our ships.

	Calliope.	*Olga.*	*Trenton.*	*Vandalia.*	*Nipsic.*
	′ ″	′ ″	′ ″	′ ″	′ ″
Length, b. p.	235 0	226 0	253 0	216 0	185 0
Beam	44 6	41 0	48 0	39 0	35 0
Mean draught	18 8	.....	20 6	17 3	14 3
Displacement	2,770	2,143	3,900	2,100	1,375
I. H. P.	4,021	2,394	2,414	1,147	839
Speed	15.0	13.92	12.6	12.0	10.7

The relative powers of the ships, brought to a common displacement of 3,900 tons (*Trenton*), are:

Calliope	2.48
Olga	1.99
Trenton	1.00
Vandalia	.98
Nipsic	1.17

These figures, taken in connection with the fact that the *Calliope* was barely able to make headway, go to show that there was little chance for the safety of our ships. That the *Calliope* did succeed in getting out speaks volumes for the engineers of the ship, and the tribute of Captain Kane to the ability and fidelity of those in charge of the machinery is well worthy of reproduction: "*If the engines held out we were safe; if anything went wrong with them, we were done for.* * * * *The way in which the engineer officers and stokers kept to their work is beyond all praise. It is a subject on which I feel keenly.*" The promotion of Staff Engineer Bourke would, therefore, seem to be well merited.

It is a matter worthy of record that, on our ships, every man stuck to his post until ordered to leave, and though two of the ships were lost, it was not through any failure of the machinery or fault of those in charge of it.

It seems to me that for bilge injection pipes of any size, there is no necessity for placing the strainers in an inaccessible position. Any substance, even a shirt, would be drawn through the pipe and would lodge in the strainer, which might be secured to the bilge injection valve chamber. With small pipes, this arrangement would not do, and it would probably be better to put the strainers near the end of the suction pipe.

PASSED ASSISTANT ENGINEER ASA M. MATTICE, U. S. N.—Two questions arise in my mind in connection with the collapse of the *Nipsic's* smoke pipe:

1st. Would the smoke pipe have been seriously damaged if it had been a standing one instead of telescopic?

2d. What is the use of a telescopic pipe anyway?

Taking up the second question first, it seems to me that there is no excuse for having put telescopic pipes on any vessel built for the last twenty years at least. My experience has been that the telescopic pipes have been of more use to give our ships the appearance of sailing vessels in port than they have to permit of the use of the mainsail at sea. I doubt if the greater first cost of the telescopic pipes and their hoisting gear, and cost of repairs, has not been much more than the cost of coal saved by them while sailing, to say nothing of the loss of draft by the inability to keep them perfectly tight. As to strength, the standing pipe has a great advantage over the telescopic. In our new cruisers, where smoke pipes are made with a double shell all the way up, it will be possible to make them immensely strong by socket-riveting at proper intervals between the two shells.

As to the great efficiency of manganese bronze screws, I attribute it more to the fact that the metal, when mixed of proper proportions, makes a very smooth casting, than to its greater strength and consequent thinness. I think that the same effect could be produced with any bronze screw by polishing. I know that in some quarters it is held that the smoothness of screw surface makes no perceptible difference, but this opinion is not compatible with the results of experiments on the friction of various surfaces moving through water. With an emery grinding wheel driven by a flexible shaft or equivalent device, and arranged to be guided in any direction by hand, a propeller surface could be polished in a short time. Why would it not be a good idea to take the bronze propeller of some vessel under repair and treat it in this way, and then compare results with previous performances of the same instrument? The cost would be insignificant compared with the possible light thrown on the subject.

I think there is only one better way to insure efficiency of the bilge pumping apparatus than making the bilge strainers perfectly accessible, and that is not to be dependent upon strainers at all, but to have centrifugal circulating pumps so arranged that they can handle everything that comes along. This cannot be done when bilge water handled by the pumps has to pass through the condenser tubes. In some of the new cruisers separate bilge deliveries for these pumps have been provided, and valves for changing from sea to bilge injection arranged so as to be operated by one lever. A portion of the water can be taken through the condenser tubes if the main engines are to be operated; but when it comes to a question of keeping the ship afloat, aside from all other considerations, all water can be thrown directly overboard. The bilge suctions of these pumps should not lead into cisterns provided with strainers. Instead of relying upon main drainage pipes running fore and aft, which are liable to be choked, sluice valves, operated from the deck, should be fitted in all water tight bulkheads. These could be operated to allow water equal to the capacity of the centrifugal pumps to pass from a bilged compartment to the engine room. The main drainage pipes should be for ordinary drainage and sanitary use only, and need not be larger than called for by the capacity of the ordinary small bilge pumps.

It has always seemed to me to be strange that our cruisers, considering the duties they are called upon to perform, are practically unprovided with any adequate means of saving life, either as regards their own crews or those of other vessels. I have never seen a single life boat on board of a cruising vessel of our Navy. There may be one or two on vessels on special service, but if so they are the exceptions which prove the rule. From the general accounts of the Apia disaster it seems that there were life preservers stowed below, but if this is so the vessels were better provided than many others in the service have been up to within a few years. I have cruised in at least two ships where the only life preservers were those for the gig's and whaleboat's crews—these boats being used in place of life boats. I doubt if any of our vessels are provided with a sufficient num-

ber of life preservers of any kind to serve for the whole crew. The life-line guns, which we don't carry, are seldom found necessary, but when we do want to use them we "want 'em bad." It does not seem unreasonable that some apparatus of the kind should form a part of the outfit of every naval vessel; but there seems to be a prejudice in the service against anything so effeminate as life preservers, life boats, etc. I do not see why the law should not at least require as much in this way on naval vessels as on passenger steamers.

CHIEF ENGINEER MCKEAN, U. S. N.—I am glad that my notes have elicited comment, and that my reviewers, on the whole, seem to agree with me. As to life preservers, I am of the opinion that they need not incite to desertion, as they could be placed in charge of one or more of the sentries always on post on a man-of-war in harbor. Nor would they have a demoralizing effect, but rather the contrary. Suppose they were served out or were accessible on a ship known to be in peril, (the boats being lost or unavailable) then each man would feel that whatever happened he could hardly drown, providing, of course, that the life-belts were of good quality; he would therefore work at his station till the very last moment, uninfluenced by anxiety as to the means of keeping afloat when the vessel sunk. At such times the Engineer and his men are in the bowels of the ship getting all the work possible out of the pumps. With no life preservers, their case is well nigh hopeless; with them, they have almost a swimming chance. For the information of Mr. Cowles I may state that there are at least two officers who, under the impression that life is worth living, even in the Navy, draw their allowance of life preserver at the beginning of the cruise and keep them within reach in their bunks.

XVII.

PHENOMENA ATTENDING SHIP PROPULSION.

[Continuation of discussion of CHIEF ENGINEER ISHERWOOD'S paper in the February number of the JOURNAL.]

BY PASSED ASSISTANT ENGINEER ASA M. MATTICE, U. S. N.

Continuing the discussion of Mr. Isherwood's paper in the February number of the JOURNAL, supplemented by his paper in the May number, I would like to say a few words regarding the points in which I differ from the able author.

Speaking of the possibility of "squatting" being caused in part by the "bow wave," Mr. Isherwood says: "*In a screw steamer there is no such sufficient wave flowing along the side of the vessel*," etc. Now, the action of these waves has been a case of careful study with those who have experimented with models in tanks, such as those at Torquay and at the works of Messrs. Denny, and the same persons have furthered their studies with experiments on full sized vessels. The fact that vessels whose bow wave hollows coming along the after body, have been lengthened by the insertion of a straight middle body and their speed thereby improved, should be a sufficient proof that the bow wave hollow *does* exert an influence. The *straight* middle body does not help the replacement of the water, as the lengthening of the after body would do, the only difference being that the hollow of the bow wave is transferred to a part of the vessel where it does less harm.

Regarding the theory that the water displaced by the screw rises *vertically* (p. 20), and that the supply of water comes to the screw in a *vertical* column (p. 104), perhaps the best method of investigation is by experiment. Now, water is not discriminating, and if by any means we can set water in motion below the surface we should produce the same result as if we set it in motion by means of a screw propeller. Such an experiment requires only the simplest apparatus. Suppose we take an ordinary

"dropping tube," such as we use to fill our fountain pens, and fill it with ink or any other colored fluid of about the same specific gravity as water. We now place this tube horizontally below the surface of still, clear water and eject the contents by pressure on the bulb. According to the above mentioned theory the colored liquid should rise *vertically* "into the elastic atmosphere, because other place for it there is absolutely none," as shown in Fig. 1. When we squeeze the bulb, however, we find that instead of acting in this manner our liquid squirts out horizontally, or nearly so, as shown in Fig. 2. Some of it may or may not reach the surface, according to the depth below the surface where we hold the tube and the velocity of ejection. It simply pushes aside the originally still water, and the particles so moved act on other particles, the final movement taking place at the surface water; but the water acted upon by our tube, or propeller, or whatever we may use, does not rise vertically, or even approximately so. Again, if water is supplied to the screw vertically from below and is projected vertically upwards, then a screw propeller can produce no current, for water will flow from *all* sides to take the place of that supplied vertically from below, and the water which rises vertically to the surface will flow in *all* directions. Suppose that we have a small tank, as shown in plan in Fig. 3, with a central division and a screw propeller in one side, there being sufficient depth of water below the propeller to allow the supposed vertical column to act. Now, according to the "vertical motion" theory we will produce no current in the tank when the propeller is set in motion, but we will see a column of water rising vertically to the surface and then spreading out in all directions. To most people it will be self-evident that such will not be the case, but we know by actual experiment that no such vertical column is seen, but that a current is set up, as indicated by the arrows, for tanks such as this have been used in experimenting with model propellers.

Now, it may be said, in support of the vertical projection theory, that although the actual water acted upon by the propeller does not move to the surface, yet it acts upon other water and that the final effect is that *some* water moves to the surface.

Very good, but how about the water which goes to the screw vertically from below? It is said, very truly, that water is nearly incompressible, and that therefore the water acted upon by the screw cannot occupy the same place as other water. But it is equally true that at ordinary temperatures water cannot be expanded any more than it can be compressed; therefore, the water which comes vertically from below must either leave a vacuum or its place must be taken by other water, and this by other water, and so on until finally, in order to produce equilibrium, we have to take water from the surface. If, then, it is intended to say that the final effect of the propeller is a surface disturbance, why is it not also said that the water which flows to the propeller comes vertically from *above* instead of from below? The one statement would be equally as correct as the other.

Mr. Isherwood also says (p. 100), that the water which fills the cavity left by the advance of a vessel also comes vertically from below, and he expresses doubt that any water flows into the cavity sideways. Now, suppose that in order to investigate this we build a trough having a cross section which just fits the cross section of the vessel, as in Fig. 4, the trough being perforated along the bottom and sides. If, now, we slide the vessel along in the trough it will leave a cavity which will be filled with water the same as if there were no trough in the way, except that all the water must come through the perforations and will, therefore, fill the cavity more slowly, so that we will be enabled to watch its motion. If all the water comes vertically from below, we will only see the jets *a*, *a*, *a*, etc., while the water will abstain from flowing sideways through the holes *b*, *b*, *b*, etc. I think it is hardly necessary to say that the latter phenomenon is improbable.

Mr. Isherwood cites the following experiment: A board was outrigged from a steam launch in a vertical position, with its broadside at right angles to the direction of motion, and immersed in the water. A cavity was thus formed which was seen to be filled by rising water, but "*the two sides of the cavity are absolutely vertical from top to bottom, no side flow of water from them entering the cavity, which is wholly filled from beneath vertically.*" If the generally accepted theory of gravitation, as applied

to liquids, sometimes expressed in the homely term that "water will run down hill," is correct, then the "absolutely vertical" sides of the cavity must have been an optical delusion. If, however, the phenomenon produced by the towed board is an actual and not an apparent one, it can be easily proven by the aid of instantaneous photography, while actual measurements of the profile of the cavity can easily be made in a number of ways.

Now, touching the subject of negative slip, let us look, for a moment, at Fig. 5. Suppose a body, *A*, to contain a motive power of some kind which actuates the screw *B*, turning in the nut *C*, the latter being firmly fixed. The body *A* will move forward at each revolution of the screw a distance equal to the pitch of the screw. Now, suppose that instead of the nut being firmly fixed it is only held up from behind by the short arms of the bell cranks *D D*, which are pivoted to some immovable object at *E E*. Let the long arms of the bell crank reach forward where they must be pushed aside by the advancing body *A*. This pushing aside will advance the nut *C*, and the body *A* will consequently advance a greater distance than the pitch of the screw at each revolution. Here the fulcrum, or fixed point, by which the reaction of the screw serves to advance the body *A* is not the nut *C*, but the latter is a medium by which the force acting along the screw is applied to the fixed points *E E*. If we consider the screw and nut only, we will say that it is impossible for *A* to advance more than one pitch in each revolution of the screw; but then we would only be looking at a portion of the problem. This action is analogous to that of a vessel and screw propeller. The vessel sets in motion a quantity of water, some or all of which subsequently becomes the nut or fulcrum on which the screw propeller acts. No matter how fine the form of the ship may be, this action must necessarily take place as long as there is any friction between the water and the skin of the ship, whereby the former is set in motion. If the ship is of bluff form the action will be greater, and may result in the phenomenon of negative slip. Fig. 5 shows only one of numerous mechanical arrangements by which this theory can be illustrated. It would not be difficult to imagine an arrangement in which the friction

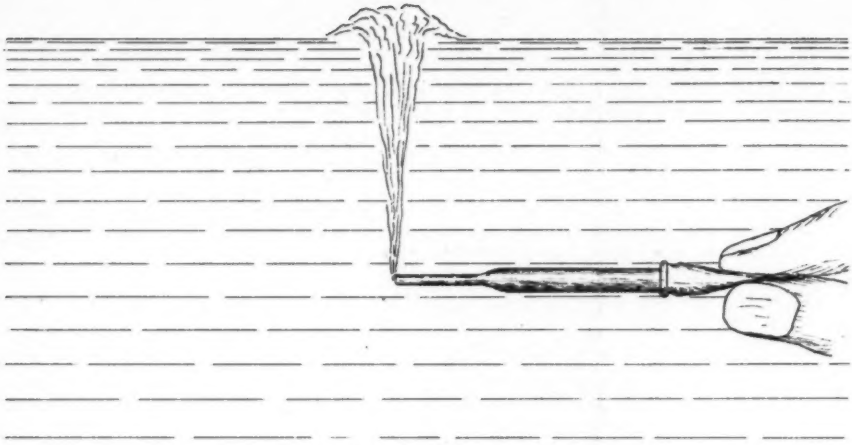


Fig. 1.

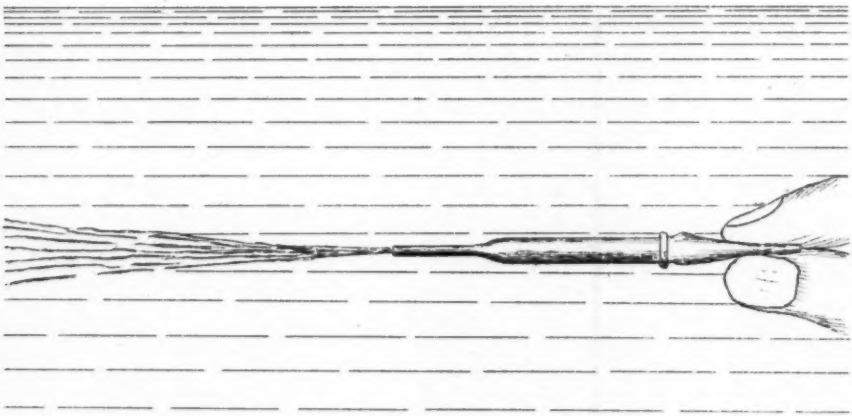


Fig. 2.

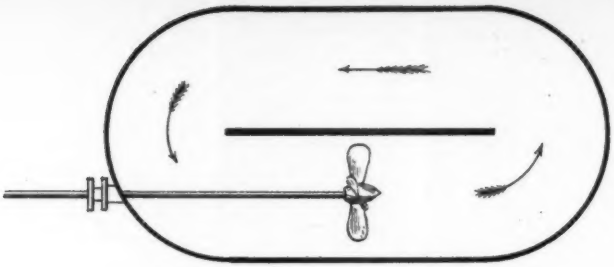


Fig. 3.

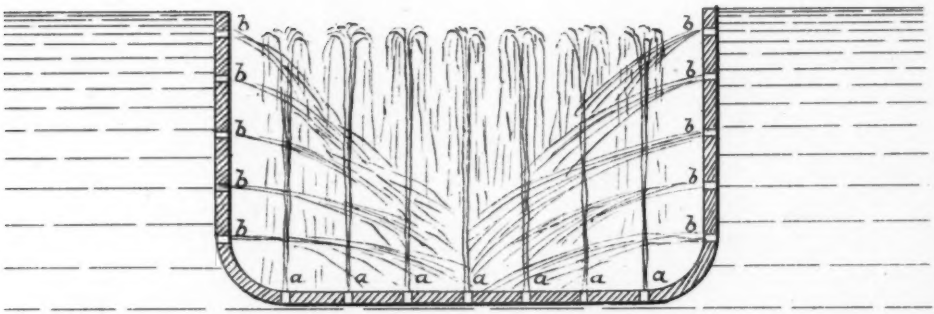


Fig. 4.

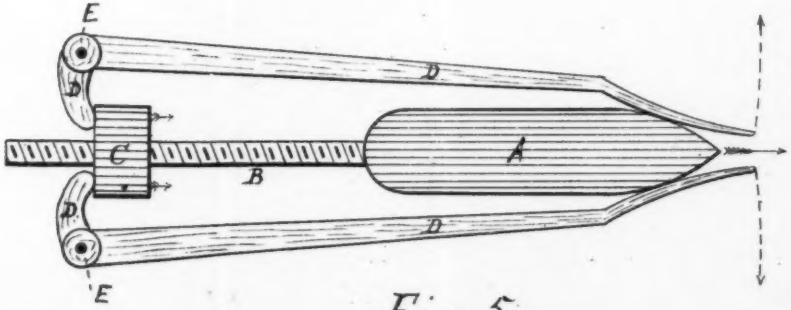


Fig. 5.

of the parts would produce the forward motion of the nut, instead of the arrangement shown, which would be a still closer imitation of the negative slip phenomenon. As to whether or not negative slip is ever observed in our vessels, I can say that I have served on board two steamers where it was not uncommon. One of them, the *Juniata*, can always be counted on to show negative slip when full of stores and with a deck load of coal, whereby her bluff stern is brought down into the water. As she has just returned from a cruise, it would be interesting to hear from her officers whether they ever observed this to be the case or not. It would also be interesting if other engineers in the naval service and merchant marine would communicate to the JOURNAL their experiences in this matter.

REPORT ON THE PERFORMANCE OF THE MACHINERY OF THE S. S. *METEOR*.

[Abstract of a paper read before the Institution of Mechanical Engineers, England, by PROF. A. B. W. KENNEDY, F. R. S., May 1, 1889.]

[Want of space has prevented the reprinting in full of this report, which, without exaggeration, may be said to be the most valuable record of marine engine data which has appeared for some time. Hitherto we have been compelled to accept assertions and estimates which, to well informed engineers, appeared questionable at best. Now we have reliable information from so high an authority as Prof. Kennedy, procured under his own supervision and with the conditions of every-day practice. The skill and care with which all of Prof. Kennedy's experiments are conducted are too well known to need further comment than that the marine engineering profession has cause to congratulate itself on this valuable result of his painstaking labor.]

The steamship *Meteor*, of the London and Edinburgh Shipping Co., has the following dimensions: Length between perpendicu-

lars, 261 feet; beam, 32.1 feet; mean draught when tried, 15 feet 1½ inches; displacement when tried, 2,090 tons.

The engines are of the triple-expansion type, made by Messrs. J. & G. Thomson, Glasgow. The cylinders are 29⅜, 44 and 70 inches in diameter, with a stroke of 47.94 inches. The piston rods are all 7 inches in diameter. The tail rod of the H. P. cylinder is 4.45 inches in diameter, and those of the I. P. and L. P. are 4.37 inches.

The cranks are equally spaced, and follow each other in the order—high, intermediate, low.

The cylinders are jacketed on the sides, but not on the ends, the net length of the jacketed space being about four feet. Live steam is admitted separately to each jacket, each having its own reducing valve. The jackets are drained through pockets provided with gauge glasses, and during the trial water was always kept visible in these glasses.

The cylinder clearances are given by the makers as—H. P., 12.4; I. P., 9.3, and L. P., 8.02 per cent.

The H. P. cylinder has one piston valve; the I. P. and L. P. each has two. The valve gear is the ordinary link motion, and during the trial the H. P. motion was linked up as much as possible, giving a nominal cut-off of 26 inches. The I. P. and L. P. motions were not linked up. The valve gear was left untouched during the whole of the trial.

The surface condenser has 3,200 square feet of condensing surface.

The screw propeller is four bladed, having a diameter of 14 feet 10 inches, and a mean pitch of 23 feet. The actual (or developed) area of the blades is 78 square feet, and the projected area 57.6 square feet.

The engines had been last overhauled at the annual survey in March, 1888.

There are two double ended boilers with twelve furnaces. They are of steel, with Fox's corrugated flues, and have a diameter of 13 feet 6 inches, and a length of 16 feet. The total grate surface in the trial was 208 square feet, and the total tube surface 5,760 square feet. The total heating surface is 6,648

square feet, or 32 times the grate surface. The mean diameter of the flues is 3 feet 3 inches. The tubes are 2½ inches external diameter and 6 feet 4½ inches long. The furnaces and tubes open out into a common combustion chamber. There is no air admission at the bridge or anywhere except from the front and below the grate bars. There is one chimney, 7 feet 3 inches internal diameter, and 61 feet high above lower grates.

The total weight of the engines and boilers, including water in condenser, pipes and boilers, and also spare gear, is 390½ tons.

The object of the trial was to measure the coal, water and indicated horse-power, and over as long a period as possible.

Every care was taken to insure accuracy in all the observations. A continuous record of the coal thrown on the fire was kept, and also plotted graphically. The fires were not cleaned during the run, but the cleaning commenced when the trial was over, and the ashes and clinker were weighed before being thrown overboard. The coal was Scotch, from the Shawfield pit in the Wishaw district, its price at Leith being 7s. 6d. per ton.

It has been analyzed, and its calorimetric value found to be as follows:

	Per cent.
Carbon,	70.31
Hydrogen,	4.88
Water,	10.68
Ash,	3.46
Nitrogen, sulphur and oxygen,	10.67
	100.00

Reducing the hydrogen to the corresponding carbon value, each pound of coal, not allowing, of course, for the bad lumps, which formed the greater part of the clinker, is thus equivalent to 0.878 lb. of carbon, and its calorific value may be taken as 12,790 thermal units.

The temperature of the gases passing up the chimney was observed at intervals throughout the trial, the thermometer being placed at the level of the upper deck, or about 12 feet above the

top of boilers. The thermometer was long enough to reach over two feet into the chimney. It was a mercury thermometer, having the space above the mercury filled with compressed nitrogen, so as to enable it to give readings far above the ordinary boiling point of mercury. A sample of the chimney gases was collected during the trial and afterwards analyzed with the result given below. The chimney draft was measured by a U-tube at the place where the sample of gas was collected. The feed water was measured in tanks on its way from the hot well to the feed pump, the latter being a Worthington pump, entirely separate from the main engine. The system adopted was such as to give substantially accurate results with sufficient time for securing accurate readings of temperatures, and assuring the complete filling and emptying of the tanks. The water thus measured included the condensed steam passing through the cylinders, the jacket condensation, and also the steam used for heating the feed water, as well as the other quantities mentioned in the next paragraph.

The steam made by the boilers, corresponding with the measured weight of the water, all went to the main engines, except the small quantity required to drive the Worthington pump, which may fairly be considered comparable with the quantity required for the feed pump of an ordinary engine. The circulating pump, the dynamo engines, the winch engines, the steering engines, &c., were all worked from a donkey boiler which was specially kept going for that purpose. The exhaust from the circulating pump engine and that from the dynamo engine were taken into the condenser, and therefore were measured through the feed tank on their way to the boiler again. These additions to the ordinary air pump discharge more than made up for the various losses of steam through the engine, so that from time to time part of the hot well discharge had to be thrown away, and not taken back to the boiler.

Indicator diagrams were taken at half-hourly intervals throughout the whole trial. Six Crosby indicators were used, one at each end of each cylinder. The connections in all cases were through only a few inches of large pipe, having in no case more

than one bend. The revolutions were noted half-hourly on the counter, all the gauges being read at the same time.

The machinery was run under the usual conditions for a southward journey, which were fixed by the chief engineer of the vessel.

The trial was made on a voyage from Leith to London, on June 24, 1888, commencing at 1.30 A. M., and ending for the engines at 6.36 P. M., and for the boilers at 6.39 P. M. of the same day, the difference being due to waiting for the water level in the boilers to be the same as at the beginning of the trial. The trial lasted, therefore, 17 hours and 6 minutes for the engines, and 17 hours and 9 minutes for the boilers. The weather was fair throughout.

A successful analysis of one sample of chimney gases gave the following result, by volume:

	Per cent.
Carbonic acid,	12.5
Carbonic oxide,	0.8
Oxygen,	5.4
Nitrogen,	81.2

This sample was collected at 11.30 A. M., under normal conditions of working. During the greater part of the trial the fires were worked very thick—indeed, as thick as possible—and were so at the end of the trial. There was very little smoke except when the fires were being charged. The firing was quite regular at intervals of about twenty-four minutes.

The following are totals and means for the trip:

Total coal burned,	68,693 lbs.
Coal burned per hour,	4,005 "
Total ash,	1,671 "
Ash, as per cent. of total coal,	2.43
Total clinker,	2,806 lbs.
Clinker, as per cent. of total coal,	4.08
Refuse from coal, per cent.,	6.51
Mean temperature of escaping chimney gases,	791° Fahr.
Mean chimney draft, inches of water,	$\frac{5}{16}$
Mean temperature of feed water,	163.1°

The feed is heated after leaving the hot well, and the amount of feed water used makes due allowance for this temperature.

Total amount of water used,	512,150	lbs.
Water used per hour,	29,860	"
Total number of revolutions,	73,650	
Average revolutions per minute,	71.78	
Mean barometric pressure,	14.9	lbs.
Mean boiler pressure (above atmos.),	145.2	"
Mean pressure in H. P. jacket (above atmos.),	131.0	"
Mean pressure in I. P. jacket (above atmos.),	77.5	"
Mean pressure in L. P. jacket (above atmos.),	56.8	"
Mean pressure in first receiver (above atmos.),	36.5	"
Mean pressure in second receiver (above atmos.),	6.2	"

The gauge for boiler pressure was checked by a standard gauge. The others were not, and their readings must therefore be considered approximate.

Mean pressure during admission to H. P. cylinder (from diagrams), 134.4 lbs.

The actual initial pressure (or pressure just at commencement of stroke) was practically the same as this in the top diagrams, and six or seven pounds higher in the bottom diagrams. The difference between the boiler pressure and the average admission pressure was thus 10.8 lbs. per square inch.

Mean vacuum in condenser (per gauge),	12.17	lbs.
Mean vacuum in L. P. cylinder (per diagrams),	11.6	"
Absolute back pressure in condenser,	2.73	"
Absolute back pressure in L. P. cylinder,	3.3	"

The mean effective pressures in the cylinders were as follows:

Cylinder.	Top.	Bottom.	Mean.
High pressure,	60.10	56.82	58.46
Intermediate,	20.47	18.54	19.50
Low pressure,	12.22	12.55	12.38

The corresponding indicated horses-power were:

H. P. cylinder,	662
I. P. cylinder,	507
L. P. cylinder,	825
Aggregate indicated horse-power,	1,994

The set of diagrams, Figs. 1, 2 and 3, corresponds very nearly to this mean.

Boiler Efficiencies.—The rate of combustion in the furnaces was 19.25 lbs. of coal per square foot of grate, or 0.602 lbs. per square foot of heating surface per hour. The evaporation was at the rate of 7.46 lbs. of water per pound of coal. The temperature of feed being 163° and of evaporation 363°, each pound of steam required the addition of 1,062 thermal units. The equivalent evaporation from and at 212° is therefore 1.10 lbs. per pound actually evaporated, making the equivalent evaporation per pound of coal 8.21 lbs., and per pound of the combustible portion of the fuel 9.62 lbs.

The equivalent amount of heat utilized per pound of coal was 7,922 thermal units, or say 62 per cent. of the whole calorific value of the fuel, which per centage, therefore, represents the actual boiler efficiency. The total nominal calorific value of the fuel burnt per minute was 853,900 thermal units. Although it can not be assumed that the analysis of the chimney gases already given was a fair average, it has been thought worth while to work it out. It thus appears that the weight of air per pound of carbon was about 22 lbs., and per pound of coal about 15.5 lbs. The loss of heat in raising the temperature of the furnace gases works out to 21.9 per cent. of the calorific value of the fuel, the loss by formation of carbonic oxide to 3.6 per cent., and that due to the evaporation of the moisture in the fuel to 1.2 per cent. The sample of coal analyzed being free from clinker, the 4 per cent. of clinker may be said to correspond roughly to a loss of about 3 per cent. of the whole heat. These quantities foot up to 91.7 per cent. of the whole heat of combustion, and the balance must include, among other things, all losses by radiation. The average rate of transmission of heat through the material of the boiler was 5,244 thermal units per square foot of heating surface per hour.

Engine Efficiencies.—The measurement of feed water shows that the quantity used per I. H. P. per hour was, within the limits of accuracy, 15 lbs. For purposes of comparison with a "perfect" engine, it may be assumed that the higher limit of tempera-

ture is that of the boiler steam, 363° Fahr., while the lower limit may be taken as 120° Fahr. It was, unfortunately, impossible to ascertain the temperature of the condensed steam as it entered the hot well, but, considering the good vacuum, the estimate of 120° is probably not far out. On this basis, the efficiency of these engines works out to 54.6 per cent of that of a "perfect" engine working between the same limits of temperature. This is a high efficiency, but corresponds to the low feed water consumption. The absolute engine efficiency, or ratio of the heat turned into work, to the total heat received by the feed water, was 16.1 per cent.

Total Efficiency.—The combined efficiency of the boilers and engines, or ratio of heat turned into work, to the total heat of combustion of the fuel, was almost exactly 10 per cent.

Steam by Indicator Diagrams.—Careful measurements of all the diagrams taken were made to ascertain the proportion of steam accounted for by them, and the following are the results, the actual amount of feed water used per revolution being 6.93 pounds.

Proportion of steam accounted for by indicator diagrams.	Pounds per revolution.	Percentage of total feed.	Percentage in jackets or present in cylinders as water.
Steam present in high-pressure cylinder after cut-off, when the pressure was 110 lbs. above atmosphere	5.34	77.1	22.9
Steam present in intermediate cylinder when the pressure was 22 lbs. above atmosphere	5.56	80.2	19.8
Steam present in low-pressure cylinder near end of expansion when the pressure was 4 lbs. below the atmosphere	5.22	75.3	24.7

It will thus be seen that even in these very economical engines, and with a liberal allowance for the steam used in the jackets, which, unfortunately, could not be measured separately, there must have been a considerable amount of cylinder condensation.

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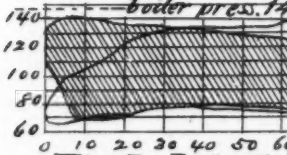
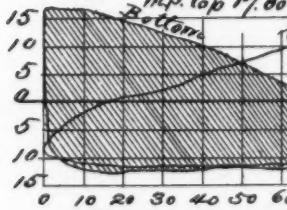
Fig. 4. H.P. C
m.p. top 51.7; bot


Fig. 5. Int. Cy
mp. top 31.4; bo

Fig. 6. L.P. Cy
m.p. top 17. bo


Per cent of S

I.H.P. H.P. C
do Int.
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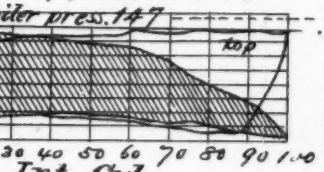
do total

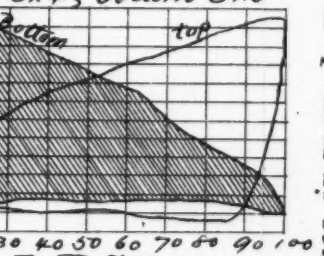
S. S. METEOR

full gear astern
. Total IHP 2660.

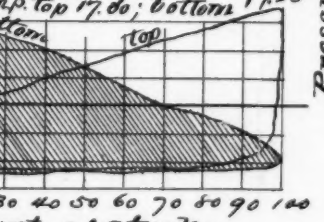
H. P. Cyl.
51.7; bottom 45.9



Int. Cyl.
31.4; bottom 31.6



L. P. Cyl.
p. top 17.80; bottom 17.25



ent of stroke

H. P. Cyl.	585.
Int. do	867.
L. P. do	1208.
total	2660.

Recs. 72. Total IHP 2009.4

Fig. 1. H. P. Cylinder
m. p. top 59.8; bottom 57.6

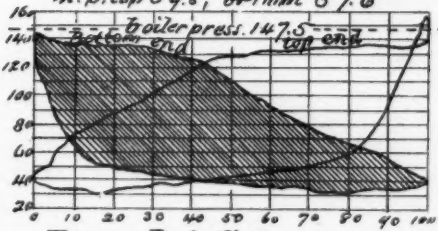


Fig. 2. Int. Cyl.
m. p. top 20.47; bottom 18.79

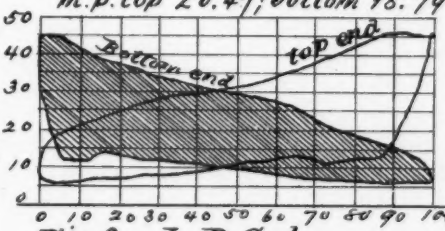
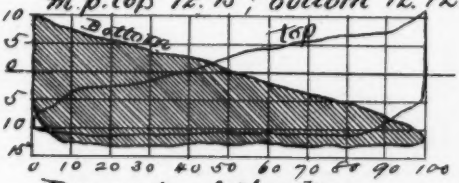


Fig. 3 L. P. Cyl.
m. p. top 12.15; bottom 12.72



Pressures in pounds per square inch

Per cent of stroke

IHP	H.P. Cyl.	666.5
do	Int. do	511.7
do	L.P do	831.2
do	total	2009.4

Coal Consumption.—The total coal put on the fires, 4,005 pounds per hour, corresponds to 2.01 pounds of coal per indicated horse-power per hour. This corresponds to 1.76 pounds of carbon value per I. H. P. per hour, or say 427 thermal units per I. H. P. per minute. As each I. H. P. per minute is equivalent to only 42.75 thermal units, this makes the combined efficiency of boilers and engines 10 per cent., as given above. The mean speed between Leith and Cromer, which practically covers the trial, was 14.6 knots.

When the vessel got into port and was being berthed, a set of cards was obtained with the engines going astern. These are given in figs. 4, 5, and 6, all the links being in full gear. The following are the particulars of these cards:

Boiler pressure above atmosphere,	147 pounds.
Revolutions per minute,	76
Vacuum in inches of mercury,	27
Mean pressure—H. P. cylinder,	48.8 pounds.
Mean pressure—I. P. cylinder,	31.5 pounds.
Mean pressure—L. P. cylinder,	17.1 pounds.
Indicated horse-power—H. P. cylinder,	585
Indicated horse-power—I. P. cylinder,	867
Indicated horse-power—L. P. cylinder,	1,208
Indicated horse-power—total	2,660

It is interesting to compare the results thus obtained with those when running in forward gear, as showing the effect of altering the sequence of the cranks, which under these circumstances follow in the order—high, low, intermediate.

[For the complete paper, with additional sets of indicator diagrams and notes of the discussion which followed its reading, see *Engineering* for May 10, 1889.—Ed.]

MEMORANDA OF ACTS OF CONGRESS APPLYING TO NEW VESSELS.

The naval appropriation act, approved August 5, 1882, appropriated $1,750,000 for the Bureau of Construction and Repair, and provided as follows:

Any portion of said sum not required for the purposes aforesaid may be applied toward the construction of two steam cruising vessels of war, which are hereby authorized, at a total cost, when fully completed, not to exceed the amount estimated by the late Naval Advisory Board for such vessels, the same to be constructed of steel, of domestic manufacture, having as near as may be a tensile strength of not less than sixty thousand pounds to the square inch, and a ductility in eight inches of not less than twenty-five per centum; said vessels to be provided with full sail-power and full steam-power.

The naval appropriation act, approved March 3, 1883, appropriated—

For the construction of the steel cruiser of not less than four thousand three hundred tons displacement now specially authorized by law, two steel cruisers of not more than three thousand nor less than two thousand five hundred tons displacement each, and one dispatch boat, as recommended by the Naval Advisory Board in its report of December twentieth, eighteen hundred and eighty-two, one million three hundred thousand dollars; and for the construction of all which vessels, except their armament, the Secretary of the Navy shall invite proposals from all American ship-builders whose ship-yards are fully equipped for building or repairing iron and steel steamships, and constructors of marine engines, machinery, and boilers; and the Secretary of the Navy is authorized to construct said vessels and procure their armament at a total cost for each not exceeding the amounts estimated by the Naval Advisory Board in said report, and in the event that such vessels or any of them shall be built by contract, such building shall be under contracts with the lowest and best responsible bidder or bidders, made after at least sixty days' advertisement, published in five of the leading newspapers of the United

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PPLYING

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Name of vessel.	Type.	Keel laid.	Act of Congress.	Contractor or place of
Chicago	Protected cruiser	1883	Aug. 5, 1882, and Mar. 3, 1883	John Roach & Son
Boston	Protected cruiser	1883	Aug. 5, 1882, and Mar. 3, 1883	John Roach & Son
Atlanta	Protected cruiser	1883	Aug. 5, 1882, and Mar. 3, 1883	John Roach & Son
Dolphin	Dispatch vessel	1883	Aug. 5, 1882, and Mar. 3, 1883	John Roach & Son
Newark	Protected cruiser	1888	Mar. 3, 1885, and Mar. 3, 1887	Wm. Cramp & Sons
Charleston	Protected cruiser	1887	Mar. 3, 1885	Union Iron Works
Yorktown	Gunboat	1887	Mar. 3, 1885	Wm. Cramp & Sons
Petrel	Gunboat	1887	Mar. 3, 1885	Columbian Iron Works
Baltimore	Protected cruiser	1887	Aug. 3, 1886	Wm. Cramp & Sons
Torpedo Boat No. 1	Sea-going torpedo boat	1888	Aug. 3, 1886	Herreshoff Manufacturing
Vesuvius	Dynamite cruiser	1887	Aug. 3, 1886	Dynamite Gun Co.††
Philadelphia	Protected cruiser	1888	Mar. 3, 1887	Wm. Cramp & Sons
San Francisco	Protected cruiser	1888	Mar. 3, 1887	Union Iron Works
Concord	Gunboat	1888	Mar. 3, 1887	Quintard Iron Works
Bennington	Gunboat	1888	Mar. 3, 1887	Quintard Iron Works
Maine	Armored cruiser	1889	Aug. 3, 1886	Hull, New York Navy-Ya Quintard Iron Works.
Texas	Armored battle ship	1889	Aug. 3, 1886	Hull, Norfolk Navy-Yard; r mond Locomotive and Ma
Puritan	Monitor	1875	Aug. 3, 1886	John Roach & Son
Monadnock	Monitor	1874	Aug. 3, 1886	Mare Island Navy-Yard
Amphitrite	Monitor	1874	Aug. 3, 1886	Harlan & Hollingsworth C
Terror	Monitor	1874	Aug. 3, 1886	Wm. Cramp & Sons
Miantonomoh	Monitor	1874	Mar. 3, 1887	John Roach & Son
	Armored coast defense vessel		Mar. 3, 1887	Union Iron Works
No. 2	Armored cruiser		Sept. 7, 188	
No. 6	Protected cruiser		Sept. 7, 188	
No. 7	Protected cruiser		Sept. 7, 188	
No. 8	Protected cruiser		Sept. 7, 188	
No. 9	Protected cruiser		Sept. 7, 188	
No. 10	Protected cruiser		Sept. 7, 188	
No. 11	Protected cruiser		Sept. 7, 188	
	Practice vessel		Sept. 7, 188	
	Armored cruising monitor		Mar. 2, 188	
	Dynamite cruiser No. 2		Mar. 2, 188	
No. 12	Protected cruiser		Mar. 2, 188	
No. 13	Protected cruiser		Mar. 2, 188	
	Harbor defense ram		Mar. 2, 188	
	Steam tug		Mar. 2, 188	
	Steam tug		Mar. 2, 1889	
	Steam tug		Mar. 2, 1889	
	Steam tug		Mar. 2, 1889	

* Without coal. ** C

GENERAL DESCRIPTIVE T

f building.	Limit of cost.	Contract price hull and machinery.	Whe co	n to be mpleted.	Extension of time.	When launched.	Displacement.	Length betw'n perpendiculars.	Breadth.
							Tons.	*Feet.*	*Feet.*
	$1,248,000	$889,000	Jan.	26, 1885		Dec. 5, 1885	4,500	315	48⅛
	783,500	619,000	Jan.	23, 1885		Dec. 4, 1884	3,189	270	42
	783,500	617,000	Ja	23, 1885		Oct. 9, 1884	3,189	270	42
	399,000	315,000	Ju	23, 1884		April 12, 1884	1,485	240	32
	1,300,000	1,248,000	Oc	27, 1889			4,083	310	49⅛
	1,100,000	1,017,500	Ju	28, 1888	Nov. 20, 1888	July 24, 1888	3,730	300	46
	520,000	455,000	Jan.	31, 1888	May 20, 1888	April 28, 1888	1,700	230	36
	275,000	247,000	Dec	27, 1888		Oct. 13, 1888	890	175	31
	1,500,000	1,325,000	June	17, 1887	Nov. 20, 1888	Oct. 6, 1888	4,413	315	48½
ng Co	100,000	82,750	June	1, 1889			99*	135	15
	350,000	350,000	Feb.	11, 1888	May 20, 1888	April 28, 1888	725	246½	26 5/12
	1,500,000	1,350,000	Oct.	27, 1889			4,324	315	48½
	1,500,000	1,428,000	Oct.	26, 1889			4,083	310	49⅛
	550,000	490,000	May	15, 1889	Aug. 23, 1889		1,700	230	36
	550,000	490,000	May	15, 1889	Aug. 23, 1889		1,700	230	36
-Yard; mach'y,	2,500,000	735,000‡	Oct.	3, 1892			6,648	310	57
; mach'y, Rich- Machine Works.	2,500,000	634,500‡	Nov	30, 1892			6,300	290	64½
						Dec. 6, 1882	6,060	280	60
						Sept. 19, 1883	3,815	250	55½
	‡‡3,178,046					June 7, 1883	3,815	250	55½
Co						Mar. 24, 1883	3,815	250	55½
							3,815	250	55½
	2,000,000	1,628,950	Dec.	14, 1892			4,000	256	59
	3,500,000						7,500		
	1,800,000						5,300		
	1,100,000						3,000	300	42
	1,100,000						3,000	300	42
	700,000						2,000	257	37
	700,000						2,000	257	37
	700,000						2,000	257	37
	260,000						800	.....	.....
	1,500,000						3,030	235	55
	350,000						686		
	700,000						1,000	.....	.....
	700,000						1,000	.....	.....
							2,000		
	35,000								
	35,000								
	35,000								
	35,000								

Coal for 300 knots at maximum speed. †† Sublet to W... n. Cramp & Sons. ‡ Two runs over 2½ knots course. ‡ Machinery only. †

L DESCRIPTIVE TABLE OF NEW SHIPS FOR U.

When launched.	Displacement.	Length betw'n perpendiculars.	Breadth.	Mean draft.	Coal capacity.	Type of engines.	Type of boilers.
	Tons.	*Feet.*	*Feet.*	*Feet.*	*Tons.*		
Dec. 5, 1885	4,500	315	48⅛	19	940	Twin-vert. 2x, beam.....	Hor. ret. fire tube .....
Dec. 4, 1884	3,189	270	42	17	500	Single-hor. back act., 2x..	Hor. ret. fire tube .....
Oct. 9, 1884	3,189	270	42	17	500	Single-hor. back act., 2x..	Hor. ret. fire tube.....
April 12, 1884	1,485	240	32	14¼	286	Single-vert., 2x.....	Hor. ret. fire tube.....
.....	4,083	310	49⅛	18¾	400 to 850†	Twin-hor., 3x.....	Hor. ret. fire tube.....
July 24, 1888	3,730	300	46	18½	328 to 800†	Twin-hor., 2x.....	90 lbs. hor. direct fire tube .....
April 28, 1888	1,700	230	36	14	400	Twin-hor., 3x.....	160 lbs. hor. direct fire tube .....
Oct. 13, 1888	890	175	31	11 7/12	160	Single-hor. back act., 2x..	100 lbs. hor. direct fire tube .....
Oct. 6, 1888	4,413	315	48½	19½	400 to 900†	Twin-hor., 3x.....	135 lbs. hor. ret. fire tube .....
.....	99*	135	15	3 7/12	**	Twin-vert., 4x.....	250 lbs. Thornycroft.....
April 28, 1888	725	246½	26 5/12	9	140	Twin-vert., 3x.....	160 lbs. hor. direct fire tube .....
.....	4,324	315	48½	19⅛	400 to 850†	Twin-hor., 3x.....	160 lbs. hor. ret. fire tube .....
.....	4,083	310	49⅛	18¾	350 to 850†	Twin-hor., 3x.....	135 lbs. hor. ret. fire tube .....
.....	1,700	230	36	14	393	Twin-hor., 3x.....	160 lbs. hor. direct fire tube ..
.....	1,700	230	36	14	393	Twin-hor., 3x.....	160 lbs. hor. direct fire tube .....
.....	6,648	310	57	21½	400 to 822†	Twin-vert., 3x.	135 lbs. hor. ret. fire tube .....
.....	6,300	290	64½	22½	500 to 950†	Twin-vert., 3x.....	150 lbs. hor. ret. fire tube ..... 80 lbs. hor. ret. fire tube .....
Dec. 6, 1882	6,060	280	60	18½	580	Twin-hor., 2x.....	
Sept. 19, 1883	3,815	250	55½	14½	.....	Twin-hor., 3x.....	160 lbs. hor. ret. fire tube .....
June 7, 1883	3,815	250	55½	14⅛	332	Twin inclined, 2x.....	80 lbs. hor. ret. fire tube .....
Mar. 24, 1883	3,815	250	55½	14⅛	332	Twin inclined, 2x.....	80 lbs. hor. ret. fire tube .....
.....	3,815	250	55½	14⅛	332	Twin inclined, 2x.....	80 lbs. hor. ret. fire tube .....
.....	4,000	256	59	14½	.....	Twin-vert., 3x.....	160 lbs. { 2 hor. ret. fire tube and coil or tubulous boilers.
.....	7,500						
.....	5,300						
.....	3,000	300	42	18	.....	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	3,000	300	42	18	.....	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	2,000	257	37	14½	200	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	2,000	257	37	14½	200	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	2,000	257	37	14½	200	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	800	.....	.....	.....	.....	Twin-vert., 3x.....	160 lbs. hor. direct fire tube .....
.....	3,030	235	55	14½	.....	Twin-vert., 3x.....	160 lbs. hor. ret. fire tube .....
.....	686						
.....	1,000	.....	.....	.....	.....	Twin-vert., 3x.....	
.....	1,000	.....	.....	.....	.....	Twin-vert., 3x.....	
.....	2,000						

runs over 2½ knots course. ‡ Machinery only. † Normal and total capacity. ‡‡ Department's estimate. ⁂ of completion, under Act o

Number and size of boilers.	Contract I. H. P.	I. H. P. on trial.	Contract speed.	Speed on trial.	Premium and penalty for I. H. P.
			Knots.	*Knots.*	
5 double 9′×26′1″ long, 2 single	5,000	5,083.7	14	15.3▽	
8 single 11′8″×9′9″ long	3,500	3,780	...	13.8▽	
8 single 11′8″×9′9″ long	3,500	3,345	...	15.54	
2 double 11′×18′3″ long 2 single 11′×9′6″ long	2,300	2,253	...	15.5	
4 double 13′6″×19′6″ long	8,000	.....	...	.....	$100 for each I. H. P. above or below contract. Minimum acceptable 7,000.
3, 11′×19′3″ long; 3, 11′6″×19′3″ long	7,000	.....	...	.....	$100 for each I. H. P. above or below contract. Minimum acceptable 6,000.
4, 10′×16′ long	3,000	3,392	...	16.14	$100 premium and $300 penalty for each I. H. P. above or below 3,000; minimum acceptable, 2,500.
2, 8′8″×18′4½″ long	1,100	.....	...	.....	$100 for each I. H. P. above or below contract. Minimum acceptable 1,000.
4 double 14′8″×17′8″ long	9,000	.....	...	.....	$100 for each I. H. P. above or below contract. Minimum acceptable 8,000.
2	.....	.....	20	.....	
4, 9′×19′8″ long	3,200‡	.....	20	.....	
4 double, 14′×20′ long	.....	.....	19	.....	
	.....	.....	19	.....	
4, 9′9″×17′6″ long	3,400	.....	...	.....	$100 for each I. H. P. above or below contra
4, 9′9″×17′6″ long	3,400	.....	...	.....	$100 for each I. H .P. above or below contra
8 single 14′8″×10′ long	9,000	.....	...	.....	$100 for each I. H. P. above or below contract. Minimum acceptable 8,000.
4 double 14′×17′ long	8,600	.....	...	.....	
8 single	3,600	.....			
4 single 12′2″×10′1″ long	3,000	.....			
6 single 12′3″×10′6″ long					
6 single 12′3″×10′6″ long	.....	1,426			
	5,400				
2 double 13′4″×20′3½″ long 2 double 14′6½″×20′3½″ long 2 single 11′2″×9′½″ long	10,000‡‡	.....	19‡‡		
2 double 11′8″×18′8½″ long 1 double 11′8″×18′1″ long 2 single 11′8″×9′½″ long	5,400‡‡	.....	18‡‡		
2, 8′9½″×17′0″ long					
8 single, 12′6″×10′11″ long	7,500	.....	17	.....	

ct of March 3, 1886. NOTE.—2x, compound engine; 3x, triple-expansion, and 4x, quadruple expansion. ▽ Bottom foul.

SHIPS FOR U. S. NAVY.

	Type of boilers.	Number and size of boilers.	Contract I. H. P.	I. H. P. on trial.	Contract speed.	Speed on trial.	
					Knots.	*Knots.*	
.....	Hor. ret. fire tube	5 double 9′×26′1″ long, 2 single.....	5,000	5,083.7	14	15.3▽	....
, 2x..	Hor. ret. fire tube	8 single 11′8″×9′9″ long.....	3,500	3,780	...	13.8▽	....
, 2x..	Hor. ret. fire tube.....	8 single 11′8″×9′9″ long.....	3,500	3,345	...	15.54	....
.....	Hor. ret. fire tube.....	2 double 11′×18′3″ long ..... / 2 single 11′×9′6″ long.....	2,300	2,253	...	15.5	....
.....	Hor. ret. fire tube.....	4 double 13′6″×19′6″ long.....	8,000	.....	...	.....	{
.....	90 lbs. hor. direct fire tube	3, 11′×19′3″ long; 3, 11′6″×19′3″ long..	7,000	.....	...	.....	{
.....	160 lbs. hor. direct fire tube	4, 10′×16′ long	3,000	3,392	...	16.14	{
, 2x..	100 lbs. hor. direct fire tube	2, 8′8″×18′4½″ long.....	1,100	.....	...	.....	{
.....	135 lbs. hor. ret. fire tube	4 double 14′8″×17′8″ long.....	9,000	.....	...	.....	{
.....	250 lbs. Thornycroft.....	2.....	.....	.....	20	.....	....
.....	160 lbs. hor. direct fire tube	4, 9′×19′8″ long	3,200‡	.....	20	.....	....
.....	160 lbs. hor. ret. fire tube	4 double, 14′×20′ long.....	.....	.....	19	.....	....
.....	135 lbs. hor. ret. fire tube	.....	.....	.....	19	.....	....
.....	160 lbs. hor. direct fire tube ..	4, 9′9″×17′6″ long.....	3,400	.....	...	.....	
.....	160 lbs. hor. direct fire tube	4, 9′9″×17′6″ long.....	3,400	.....	...	.....	
.....	135 lbs. hor. ret. fire tube.....	8 single 14′8″×10′ long.....	9,000	.....	...	.....	{
.....	150 lbs. hor. ret. fire tube ..... / 80 lbs. hor. ret. fire tube	4 double 14′×17′ long..... / 8 single.....	8,600 / 3,600	..... /	...	.....	
.....	160 lbs. hor. ret. fire tube	4 single 12′2″×10′1″ long.....	3,000	.....			
.....	80 lbs. hor. ret. fire tube	6 single 12′3″×10′6″ long.....					
.....	80 lbs. hor. ret. fire tube	6 single 12′3″×10′6″ long.....					
.....	80 lbs. hor. ret. fire tube	6 single 12′3″×10′6″ long.....	.....	1,426			
.....	160 lbs. { 2 hor. ret. fire tube and coil or tubulous boilers. }	.....	5,400				
.....	160 lbs. hor. ret. fire tube ..... / 160 lbs. hor. ret. fire tube	2 double 13′4″×20′3½″ long..... / 2 double 14′6½″×20′3½″ long.. / 2 single 11′2″×9′½″ long.....	10,000‡‡	.....	19‡‡		
.....	160 lbs. hor. ret. fire tube ..... / 160 lbs. hor. ret. fire tube ..... / 160 lbs. hor. ret. fire tube	2 double 11′8″×18′8½″ long..... / 1 double 11′8″×18′1″ long..... / 2 single 11′8″×9′½″ long.....	5,400‡‡	.....	18‡‡		
.....	160 lbs. hor. direct fire tube	2, 8′9½″×17′0″ long.....					
.....	160 lbs. hor. ret. fire tube	8 single, 12′6″×10′11″ long.....	7,500	.....	17	.....	....

nent's estimate. ‡‡ of completion, under Act of March 3, 1886. NOTE.—2x, compound engine; 3x, triple-expansion, and 4x, quadruple expansion

Premium and penalty for I. H. P.	Premium and penalty for speed.	Remarks.
.....	.....	Weight penalty. Max. I. H. P. 5,248; max. speed 16.53.
.....	.....	Max. I. H. P. 4,249; max. speed 14.9. The H. P. on trial 3,780, is the average for 6 hours.
.....	.....	
.....	.....	Max. I. H. P. 2,366.
$100 for each I. H. P. above or below contract. Minimum acceptable 7,000.	.....	Weight penalty $500 per ton, and time penalty. Contract I. H. P. to be developed on 4 hours' trial.
$100 for each I. H. P. above or below contract. Minimum acceptable 6,000.	.....	Do.
$100 premium and $300 penalty for each I. H. P. above or below 3,000; minimum acceptable, 2,500.	.....	Do.
$100 for each I. H. P. above or below contract. Minimum acceptable 1,000.	.....	Do.
$100 for each I. H. P. above or below contract. Minimum acceptable 8,000.	.....	Do.
.....	$4,000 penalty if speed is below 22 knots; $1,500 for each ¼ knot over 23 knots; and $2,000 for each ¼ knot over 24 knots.	Time penalty.
.....	.....	Time penalty.
.....	$50,000 for each ¼ knot over or under 19 knots.	Mean draft on 4 hr. trial to be 19′2½″.
.....	$50,000 for each ¼ knot over or under 19 knots.	Mean draft on 4 hr. trial to be 18′9″.
$100 for each I. H. P. above or below contract.	.....	Time and weight penalty.
$100 for each I. H .P. above or below contract.	.....	Time and weight penalty.
$100 for each I. H. P. above or below contract. Minimum acceptable 8,000.	.....	Time and weight penalty.
.....	$50,000 for each ¼ knot over or under 17 knots.	

ion. ▽ Bottom foul.

States, inviting proposals for constructing said vessels, subject to all such rules, regulations, superintendence, and provisions as to bonds and security for the due completion of the work as the Secretary of the Navy shall prescribe; and no such vessel shall be accepted unless completed in strict conformity with the contract, with the advice and assistance of the Naval Advisory Board, and in all respects in accordance with the provisions of the act of August fifth, eighteen hundred and eighty-two, except as they are hereby modified; and the authority to construct the same shall take effect at once; and the Secretary of the Navy may, in addition to the appropriation hereby made, apply to the constructing and finishing of the vessels in this clause referred to, any balance of the appropriation made to the Bureaus of Construction and Repair and Steam-Engineering for the current fiscal year or in the present act which may remain available for that purpose: *Provided*, That he shall utilize the national navy-yards, with the machinery, tools, and appliances belonging to the government there in use in the building of said ships, or any parts thereof, as fully and to as great an extent as the same can be done with advantage to the government.

The services and expenses of the two civilian expert members of the Naval Advisory Board may be paid from the appropriations for the increase of the Navy, not exceeding eleven thousand dollars.

For investigating and testing the practicability of deflective turrets designed by Passed Assistant Engineer N. B. Clark, twenty thousand dollars, to be available immediately, the investigation and test to be made by the Naval Advisory Board.

The contracts for the construction of these four vessels, the *Chicago*, the *Boston*, the *Atlanta*, and the *Dolphin*, were awarded to John Roach, who was the lowest bidder in each case.

The next legislation providing for the construction of steel vessels is contained in the Naval Appropriation Act approved March 3, 1885, which reads:

For the construction of two cruisers of not less than three thousand nor more than five thousand tons displacement, costing, exclusive of armament, not more than one million one hundred thousand dollars each; one heavily armed gunboat of about sixteen hundred tons displacement, costing, exclusive of armament, not more than five hundred and twenty thousand dollars; and one light gunboat of about eight hundred tons displacement,

costing, exclusive of armament, not more than two hundred and seventy-five thousand dollars; and authority is hereby given for the construction of said four vessels, at not exceeding the total cost for each above specified, in accordance with such final plan as may be determined upon, after a revision and reconsideration of all designs which have been heretofore made, and in the manner and conformity to the conditions and limitations provided for the construction of the new cruisers in the acts of August fifth, eighteen hundred and eighty-two, and of March third, eighteen hundred and eighty-three, except so far as said acts provide for and define the duties of Naval Advisory Board.

Under the authority of this act, bids were received for the construction of the two vessels known as cruiser No. 1 (*Newark*) and cruiser No. 2 (*Charleston*). The lowest bid received for cruiser No. 1 was $1,132,000, or $32,000 in excess of the amount appropriated by Congress for the construction of that vessel. Congress was then asked to appropriate an additional amount to enable the Department to contract for the construction of the vessel, and the necessary amount was appropriated in the act approved March 3, 1887, one section of which reads as follows:

And the Secretary of the Navy is hereby authorized to readvertise for the construction of cruiser number one, known as the *Newark*, and the limit of cost of said vessel is hereby extended to one million three hundred thousand dollars, exclusive of armament.

New proposals were accordingly called for, and the contract was awarded to Cramp & Sons at the price of $1,248,000, and the vessel is now under construction at the yards of that firm.

The contract for the construction of cruiser No. 2, the *Charleston*, appropriated for as above noted, was awarded to the Union Iron Works, San Francisco, Cal.; that for the construction of the heavily armed gunboat, known as gunboat No. 1 (*Yorktown*) was awarded to Cramp & Sons, Philadelphia; and that for the light gunboat, known as gunboat No. 2 (*Petrel*) to the Columbian Iron Works, Baltimore, Md.

The vessels are now in course of construction.

An act to increase the Naval Establishment, which was approved August 3d, 1886, reads as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the President is hereby authorized to have constructed, as hereinafter provided—

First. Two sea-going double-bottomed armored vessels of about six thousand tons displacement, designed for a speed of at least sixteen knots an hour, with engines having all necessary appliances for working under forced draught, and costing, including engines and machinery and excluding armament, not more than two million five hundred thousand dollars each. Said vessels shall have each a complete torpedo outfit and be armed in the most effective manner.

Second. One protected double-bottomed cruiser of not less than three thousand five hundred nor more than five thousand tons displacement, designed to have the highest practicable speed and furnished with the best type of modern engines, furnished with necessary appliances for working under forced draft. Said vessel shall cost, including engines and machinery and excluding armament, not exceeding one million five hundred thousand dollars.

Third. One first-class torpedo-boat, costing in the aggregate not more than one hundred thousand dollars.

SEC. 2. That the vessels hereinbefore authorized to be constructed shall be built of steel of domestic manufacture, having a tensile strength of not less than sixty thousand pounds per square inch, and an elongation in eight inches of not less than twenty-five per centum.

SEC. 3. That the President is hereby authorized to direct the completion, as hereinafter provided, of the double-turreted monitors *Puritan*, *Amphitrite*, *Monadnock* and *Terror*, at a total cost, exclusive of armament, not to exceed three million one hundred and seventy-eight thousand and forty-six dollars.

SEC. 4. That the armor used in constructing said armored vessels and for completing said monitors shall be of the best obtainable quality and of domestic manufacture, provided contracts for furnishing the same in a reasonable time, at a reasonable price, and of the required quality can be made with responsible parties. Such armor shall be accepted only after passing such tests as shall be prescribed by the Secretary of the Navy and inserted in the contracts.

SEC. 5. That the Secretary of the Navy shall cause one or more of the new vessels hereinbefore provided for to be constructed and one or more of the said monitors to be completed in one or more of the navy-yards of the United States; and if he shall be

unable to contract with responsible parties to construct or complete, at reasonable prices, all or any of the vessels hereinbefore provided for, he shall cause the same to be constructed or completed in such of the navy-yards of the United States as may be best adapted thereto.

SEC. 6. That the engines, boilers, and machinery of all the new vessels provided for by this act shall be of domestic manufacture and procured by contract, unless the Secretary of the Navy shall be unable to obtain the same at fair prices, in which case he may construct the same, or any portion thereof, in the navy-yards of the United States: *Provided*, That the Secretary of the Navy may purchase abroad only such shafting as it may be impossible to obtain in the United States in time for use in the construction of the vessels herein provided for.

SEC. 7. That the Secretary of the Navy shall not contract for the construction or completion of any of said vessels, or of their engines, machinery, or boilers, until drawings and specifications of the same shall have been provided or adopted by him; and after said drawings and specifications shall have been provided, adopted, and approved as aforesaid, and work shall have been commenced on any contract made therefor, such plans and specifications shall not be changed in any respect when the cost of such change in the execution of the work exceeds five hundred dollars, except upon the written order of the Secretary or Acting Secretary of the Navy; and if changes are thus made, the actual cost thereof and the damage caused thereby shall be ascertained, estimated, and determined by a board of naval officers to be provided for in the contract; and in any contract made pursuant to this act it shall be provided in the terms thereof that the contractor shall be bound by the determination of said board, or a majority thereof, as to the amount of increase or diminished compensation said contractor shall be entitled to receive, if any, in consequence of such change or changes. In every contract to be made under this act there shall be prescribed a period within which the work provided for in said contract, or specified portions thereof, shall be completed, and the completion of such work within the periods prescribed shall be insured by penal provisions. For the construction or completion of such vessels hereinbefore provided for as the Secretary of the Navy shall propose to have constructed or completed by contract, as well as also for the engines, boilers, and machinery hereinbefore provided for, he shall invite proposals from every American shipbuilder and other person who shall show to the satisfaction of the Secretary of the Navy that within three months from the date of the contract he

will be possessed of the necessary plant for the performance of the work in the United States which he shall offer to undertake, and such contract shall be let to the lowest and best responsible bidder or bidders, after at least sixty days' advertisement, published in five leading papers of the United States, inviting proposals for the work proposed, which work shall be subject to all such rules, regulations, superintendence by naval officers during construction, and provisions as to bonds and security for the quality and due completion of the work as the Secretary of the Navy shall prescribe; and no vessel, boiler, engine, machinery, or portion thereof shall be accepted unless completed in strict conformity with the contract; and the authority given hereby shall take effect at once. The Secretary of the Navy shall have the power to reject any or all bids made under the provisions of this act.

SEC. 8. That the sum of one million dollars is hereby appropriated towards the armament of the vessels authorized by the act of March third, eighteen hundred and eighty-five, of the vessels authorized by section one of this act, and of the unfinished monitors hereinbefore mentioned, and of the *Miantonomoh;* and the Secretary of the Navy is hereby authorized to direct the application of such portions of this sum as may be necessary to the manufacture or purchase of such tools and machinery or the erection of such structures as may be required for use in the manufacture of such armament, or any part thereof: *Provided*, That the Secretary of the Navy may contract with domestic manufacturers for the construction of such portion of the heavy guns herein provided for as may not be built by the Government.

Plans for the armored vessels were invited, and a board appointed to consider all plans submitted. This board reported in favor of plans submitted by the Barrow Ship-Buliding Company, of Barrow-in-Furness, England, for the battle-ship. The plans for the armored cruiser were prepared by the Department.

Under this act an "Armored Battle-Ship," known as the *Texas*, is now building at the navy-yard, Norfolk, Va., and "An Armored Cruiser," known as the *Maine*, is now building at the navy-yard, Brooklyn, N. Y.

Section 6 of this act provides for the machinery of these vessels to be built by contract, and contracts have been made with the Richmond Locomotive Works of Richmond, Va., for the machinery of the former, and with the Quintard Iron Works of New York for the machinery of the latter vessel.

Under authority of the second paragraph of this act, the protected cruiser, known as the *Baltimore*, is in course of construction at the works of the Wm. Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa.

The third part of section 1 of this same act appropriates for "one first class torpedo boat, costing in the aggregate not more than one hundred thousand dollars."

Under this section a sea-going torpedo boat, known as "Torpedo Boat No. 1," is under construction at the works of the Herreshoff Manufacturing Company of Bristol, R. I.

Under the authority of section 3 of this act, the monitors *Puritan*, *Terror*, and *Miantonomoh* are under completion at the New York Navy-Yard, the *Amphitrite* at the Norfolk Navy-Yard, and the *Monadnock* at the Mare Island Navy-Yard.

The act approved August 3, 1886, contains the following clause:

SEC. 9. That the Secretary of the Navy is hereby authorized to contract with the Pneumatic Dynamite-Gun Company of New York for one dynamite-gun cruiser, as follows: Said cruiser to be not less than two hundred and thirty feet long, twenty-six feet breadth of beam, seven and one-half feet draft, three thousand two hundred horse-power, and guaranteed to attain a speed of twenty knots an hour, and to be equipped with three pneumatic dynamite guns of ten and one-half inch caliber, and guaranteed to throw shells containing two hundred pounds of dynamite or other high explosives at least one mile, each gun to be capable of being discharged once in two minutes, at a price not to exceed three hundred and fifty thousand dollars; said contract to be made only on condition that there shall be a favorable report made by the existing Naval Board on the system; to be paid for as the work progresses, and upon the report of such board or boards of inspectors as the Secretary of the Navy may for that purpose appoint, reserving thirty per centum on all such payments until the whole work is completed and accepted by the Secretary of the Navy.

Under authority of this act the dynamite-gun cruiser, known as the *Vesuvius*, was contracted for, and is now in course of construction by the Pneumatic Dynamite-Gun Company, of New York.

Four additional vessels were appropriated for by the act approved March 3, 1887, as follows:

INCREASE OF THE NAVY.

SEC. 2. That for the purpose of increasing the naval establishment of the United States the President is hereby authorized to have constructed by contract two steel gun boats each of about seventeen hundred tons displacement; of the type of gunboat number one; at a cost, exclusive of armament, of not more than five hundred and fifty thousand dollars each. Two steel cruisers to be provided with such armament for each as the Navy Department may deem suitable. The cost of both of said cruisers in the aggregate, complete, exclusive of armament, and excluding any premiums that may be paid for speed for the same shall not be more than three million dollars. The sum of one million five hundred thousand dollars is hereby appropriated out of any money in the Treasury not otherwise appropriated toward the construction of said vessels.

Proposals were received for the construction of these four vessels on the 8th of August, 1887, and the contracts have been awarded, as follows:

Philadelphia (cruiser No. 4), to the William Cramp & Sons' Ship and Engine Building Company; *San Francisco* (cruiser No. 5), to the Union Iron Works; *Concord* (gunboat No. 3), and *Bennington* (gunboat No. 4), to N. F. Palmer, Jr., & Co.

The act approved March 3, 1887, also appropriated as follows:

SEC. 3. That for the purpose of further increasing the naval establishment of the United States, the sums of money hereinafter named are hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be expended by the President, in the exercise of his discretion, upon plans and specifications, to be furnished by the Navy Department:

For floating batteries or rams, or other naval structures, to be used for coast and harbor defense, one million dollars. The final cost of said floating batteries, rams, or other naval structures, exclusive of armament, shall not exceed two million dollars.

For the purchase of, and the trial and testing of torpedoes and appliances using explosives to be operated from naval vessels, floating batteries, or rams, fifty thousand dollars, which sum shall be immediately available.

That the material used in all naval structures provided for in this act, and the armament for the same shall be, so far as practicable, of American production and furnished and manufactured

in the United States, and all contracts made for their construction shall be under the provisions of the act of August third, eighteen hundred and eighty-six, entitled "An act to increase the naval establishment:" *Provided*, That the Secretary of the Navy may employ and pay out of appropriations for new ships such civilian expert aids, additional draftsmen, writers, copyists, and model-makers on the designs therefor as may be necessary.

Under this act, plans were drawn up by a board of officers consisting of Capt. R. L. Phythian, Lieutenant-Commander Converse, Passed Assistant-Engineer Mattice, and Assistant-Naval-Constuctors Bowles and Nixon, for an armored coast defense vessel of about 4,000 tons, bids for which were opened at the Navy Department April 3, 1889, and the contract awarded to the Union Iron Works of San Francisco.

The act approved September 7, 1888, appropriates for 8 vessels as follows:

INCREASE OF THE NAVY.

Construction.—That for the pupose of further increasing the naval establishment of the United States, the President is hereby authorized to have constructed, by contract, two steel cruisers of about three thousand tons displacement each, at a cost, exclusive of armament, and excluding any premiums that may be paid for increased speed, of not more than eleven hundred thousand dollars each; one steel cruiser of about five thousand three hundred tons displacement, to cost, exclusive of armament, and excluding any premium that may be paid for increased speed, not more than eighteen hundred thousand dollars; one armored cruiser of about seven thousand five hundred tons displacement, to cost, exclusive of armament, not more than three million five hundred thousand dollars; and three gunboats, or cruisers, neither of which shall exceed two thousand tons in displacement nor seven hundred thousand dollars in cost, excluding any premium that may be paid for increased speed and the cost of armament; said three gunboats, or cruisers, to be built either wholly of steel or with steel frames. The contracts for the construction of said first three cruisers shall contain provisions to the effect that the contractor guarantees that when completed and tested for speed, under conditions to be prescribed by the Navy Department, the two vessels first hereinbefore provided for, shall each exhibit a maximum speed of at least nineteen knots per hour; and the

vessel of five thousand three hundred tons displacement, a maximum speed of at least twenty knots per hour; and in the case of each vessel, for every quarter knot of speed so exhibited above said guarantee the contractor shall receive a premium over and above the contract price of fifty thousand dollars; and for every quarter knot that such vessel fails of reaching said guaranteed speed, there shall be deducted from the contract price the sum of fifty thousand dollars. And in the contract for the construction of the three last-mentioned vessels such provisions for increased speed and the premium for the same shall be made as in the discretion of the Secretary of the Navy may be deemed advisable. In the construction of all of said vessels all the provisions of the act of August third, eighteen hundred and eighty-six, entitled "An act to increase the naval establishment" as to material for said vessels, their engines, boilers, and machinery, the contracts under which they are built, the notice of, and proposals for the same, the plans, drawings, specifications therefor, and the method of executing said contracts, shall be observed and followed, and said vessels shall be built in compliance with the terms of said act, save that in all their parts said vessels shall be of domestic manufacture. If the Secretary of the Navy shall be unable to contract at reasonable prices for the building of any of said vessels, then he may build such vessel or vessels in such navy-yards as he may designate.

Steel Practice Vessel.—For the construction of one steel practice vessel of eight hundred tons, for the use of the United States Naval Academy at Annapolis, except when in emergencies it may be used for other purposes, to be built by contract in accordance with the terms of the "Act to increase the naval establishment," approved August third, eighteen hnndred and eighty-six, two hundred and sixty thousand dollars.

The act approved March 2, 1889, appropriates for five ships, as follows:

INCREASE OF THE NAVY.

To enable the President to further increase the Naval Establishment of the United States he is hereby authorized to have constructed by contract one armored steel cruising monitor, of not less than three thousand tons displacement, at a cost not exceeding one million five hundred thousand dollars—exclusive of armament, and of any premium which may be paid for increased speed—of the type, and according to the plans approved and

recommended by a naval board in their report to the Secretary of the Navy, and by him referred to and approved in his letter to the chairman of the Committee on Naval Affairs of the House of Representatives, dated January ninth, eighteen hundred and eighty-nine, to be approved by the Secretary of the Navy.

The contract for the construction of said cruising monitor, her boilers, engines, and machinery, shall contain provisions to the effect that, under conditions to be prescribed by the Navy Department, the contractor shall guaranty that the collective horse-power developed by the engines of said vessel shall equal seven thousand five hundred indicated horse-power, and that said vessel when completed and tested for speed, under conditions to be prescribed by the Navy Deparment, shall exhibit a maximum speed of not less than seventeen knots per hour; and the contract for said vessel shall contain a further provision that for every quarter of knot of speed so exhibited above said guaranty of seventeen knots the contractor shall receive a premium, over and above the contract price, of fifty thousand dollars, and for every quarter-knot that said vessel fails of reaching said guaranteed speed there shall be deducted from the contract price the sum of fifty thousand dollars. The material, boilers, engines and machinery shall be of domestic manufacture and of the latest and most approved quality and type.

The act of August third, eighteen hundred and eighty-six, entitled "An act to increase the Naval Establishment," so far as applicable, shall govern the construction of said vessel.

And the President is also hereby further authorized to contract with the Pneumatic Dynamite Gun Company for the construction of one additional cruiser of the *Vesuvius* type, of not less dimensions than that vessel, and to attain a speed under similar conditions as to trial, of twenty-one knots an hour, with an endurance of not less than fifteen days at ten knots an hour, to be armed with two pneumatic dynamite guns of fifteen-inch caliber, and to be fitted for such other armament as the Secretary of the Navy may prescribe: *Provided*, That the contractors shall guaranty a speed of twenty knots an hour, and that there shall be deducted from the contract price the sum of ten thousand dollars for every quarter knot that said vessel fails of reaching the further speed of twenty-one knots per hour: *And provided further*, That the Secretary of the Navy shall be satisfied, after official tests made with the *Vesuvius* and her guns, as to the efficiency of the armament of that vessel; and the cost of said vessel shall not exceed the sum of four hundred and fifty thousand dollars.

The President is hereby further authorized to have constructed

by contract two steel cruisers or gun-boats of the most approved type, of eight hundred to twelve hundred tons displacement, to cost in the aggregate, exclusive of armament, not more than seven hundred thousand dollars, and one ram for harbor defense, of the general type approved by the Naval Advisory Board in their report to the Secretary of the Navy of November seventh, eighteen hundred and eighty-one, of the highest practicable speed.

The act of August third, eighteen hundred and eighty-six, entitled "An act to increase the Naval Establishment," so far as applicable, shall govern the construction of the two steel cruisers or gunboats, and the ram herein authorized; and all of said vessels shall be of domestic manufacture.

Construction and Steam Machinery.—Towards the construction and completion of the new vessels heretofore and herein authorized by Congress, with their engines, boilers, and machinery, and for the payment of premiums for increased speed or horse-power under contracts now existing and to be made under this and other acts providing for increase of the Navy, four million and fifty-five thousand dollars, of which sum fifty-five thousand dollars is hereby authorized to be expended by the Secretary of the Navy upon the electric lighting of the *Miantonomoh*, *Terror*, *Monadnock*, *Petrel*, and *Vesuvius*, in addition to the amounts heretofore authorized to be expended on the said vessels.

Armament.—Towards the armament and armor of domestic manufacture for the vessels authorized by the act of March third, eighteen hundred and eighty-five; of the vessels authorized by sections one and two of the act of August third, eighteen hundred and eighty-six; of the unfinished monitors mentioned in section three of the same act; of the *Miantonomoh;* of the vessels authorized by the act approved March third, eighteen hundred and eighty-seven, and of the vessels authorized by the act approved September seventh, eighteen hundred and eighty-eight, and this act, two million five hundred thousand dollars.

The act of Congress approved March 2, 1889, and headed "An act making appropriations for the Naval Service for the fiscal year," &c., provides under the Bureau of Construction and Repair for four steam tugs, as follows:

"For the purchase, or construction by contract, of four steam tugs, the cost of which shall not exceed thirty-five thousand dollars each, one for use at the navy-yard, Washington, District of Columbia, and one at the navy-yard, Mare Island, California, in all, one hundred and forty thousand dollars."

CASUALTIES AND REPAIRS.

[It is the purpose of the Council to illustrate under this head the practical methods adopted on board ship for doing such work as would ordinarily have to be done in a shop, or ingenious methods which have been devised for doing such work as that described below. In sending in such items sketches should be made on plain white paper, and rolled, not folded.]

BREAKDOWN OF AIR-PUMP GEAR.—In July, 1888, the paddle-wheel steamer *Tallapoosa*, P. A. Engineer Geo. H. Kearney in charge of the machinery, ran aground in the Parana River. Water drawn through the draincock on circulating pump contained no sand, and soundings showed plenty of water near injection strainer, so the engine was backed and the vessel finally gotten off. Upon starting the engine again, the condenser at once formed a good vacuum, but in six minutes after receiving four bells, the pump connections became seriously out of order. It was found that the air-pump rock-shaft was twisted, throwing the rocker-arm about 31° towards the pump, and the plunger, working water of condensation on one side and circulating water on the other, was about 2¼ inches beyond the end of the barrel; several buckets of sand and small gravel were found in the channel-ways, almost all the condenser-tubes were choked with sand, and the rock-shaft (8 inches in diameter), was found slightly cracked circumferentially and longitudinally. Men were set to haul on tackles attached to the ends of the rocker-arms, to discover if shaft was broken completely through, but no more twist could be obtained.

Efforts were first made to remove the keys securing air-pump arm, but the latter could not be started with sledges, jacks and heating. The portable forge was then rigged close up to the shaft between two of the bearings, an air-pipe leading from the air-compresser (for steering-gear and aërating apparatus) was connected to serve as a blast, and water was run on the shaft beyond the forge to keep the heat from spreading to the bearings. The shaft was heated to a bright red for a length of 18 inches, and then twisted back 30° with tackles.

The air-pump rocker-arm was blocked fast and tackles attached, with men on each, to pull on the motion rocker-arms with a leverage of 6 feet 10 inches from center of shaft, but with this purchase no new twist could be detected though a long tell-tale was fitted for the purpose; holes were drilled through cracks to find their depth, part of the top brass of middle bearing was cut out so that the cracks could be watched, and scores and shoulder in air-pump barrel smoothed. Heavy blocking was built up under the shaft to support it in case it should break, and chain rigged to hold it from being forced forward in that event. The engine was jacked around with bonnets off; it was found that though the plunger over-rode slightly at one end, it still had solid bearing in the barrel, and everything was closed up. Moderate steam was raised and the engine was worked by hand in both directions. The ship was then got under way with steam, at first running very slowly with reflux valve on circulating pump open and drain-cock open on air-pump end to vitiate the vacuum and relieve the pump. Finally, steam was permitted to come up gradually, and, everything in time resuming its normal condition, a full-power trial was made, upon which the pump gear worked "perfectly well."

SPACE OCCUPIED BY MACHINERY OF SOME OF THE NEW CRUISERS.

COMPILED BY MR. S. S. JORDAN, ASSOCIATE.

[Presented at meeting of Philadelphia Branch May, 29, 1889.]

	Length of boiler compartments.	Length of engine compartments.	Length of athwartship bunkers.	Total length of machinery spaces.	Length of ship between perpendiculars.	Beam.	Mean draft.	Displacement.
Chicago	86′0″	56′0″	None.	142′0″	315′	48′2″	19′	4,500
Boston	64′0″	32′0″	None.	96′0″	270′	42′0″	17′	3,189
Atlanta	64′0″	32′0″	None.	96′0″	270′	42′0″	17′	3,189
Baltimore	68′0″	58′0″	24′0″	150′0″	315′	48′6″	19′6″	4,400
Philadelphia	72′0″	56′0″	22′0″	150′0″	315′	48′6″	19′2¾″	4,324
Newark	79′0″	40′6″	9′0″	128′6″	310′	49′2″	18′9″	4,082.9
Yorktown	58′8″	44′0″	3′4″	106′0″	228′	36′0″	14′	1,700
Vesuvius	66′6″	33′3″	3′6″	103′3″	246′3″	26′6″	9′3″	805

SHIPS.

UNITED STATES.—*Baltimore.*—This protected cruiser, building by the William Cramp & Sons' Ship and Engine Building Company, Philadelphia, from the designs purchased from Sir William Armstrong, Mitchell & Co., after a dock trial during the last week in June, was, on the 10th of July, taken out by the contractors for a preliminary run with forced draft, to see that everything was in proper condition for the official trial. She returned on the 12th, and will soon be ready for the official trial, a few alterations having been found necessary, which will probably not be completed before the 20th of August.

Charleston.—After a week or ten days spent in running the engines at the dock for the purpose of adjusting the main bearings and various working parts, she went to sea on the 7th of May for the official trial, which, according to the terms of the contract, was to be for four consecutive hours, the required I. H. P. being 7,000. The place selected for the trial was Santa Barbara Channel. During the run down from San Francisco the speed of the engines was gradually increased from 70 to 100 revolutions, but when running at the higher speed the cross-head slides heated. After arrival at Santa Barbara it was determined to make the official run on the 10th; fog, however, prevented it until the following day, when for 17 minutes the engines were run at a speed of 107 and 106 revolutions. It was impossible to continue the trial owing to the heating of the cross-head slides, and, as it was evident that a successful trial could not be run, it was determined to return to San Francisco. On the run up the engines were speeded for a few minutes up to 105 revolutions, but with the same result as during the official trial. Besides this, the thrust bearing got so hot as to necessitate stopping the engines and removing some of the collars, which had warped. It appears that in backing the thrust collars bear directly on the cast iron block, and small particles of cast iron becoming abraded worked over to the forwarded composition rings, thus causing the heating.

The trouble with the cross-head guides was due to the fact that the guide was a steel bar and the slippers of cast iron, without any anti-friction metal intervening. The result, at such high speed of reciprocation, may be readily imagined. Mr. Marshall, (of the firm of R. & W. Hawthorne, Leslie & Co., Newcastle, England, who designed the machinery,) in a paper on High Speed Engines, read before the Northeast Coast Institution of Engineers and Shipbuilders, thus describes a similar experience with the same design, presumably in the *Naniwa-Kan*: "In the first instance, we had considerable trouble with the guide shoes and motion bars, but that arose from the fact that we adopted the same principle and material for the guide shoes of the motion bars, which were of steel, as we did when the bars were of cast iron, as was the common practice in engines working at lower speed in ordinary merchant vessels. We found that the bars heated when working above a certain velocity. The oil was burnt off, and the application of water rendered the abraded surfaces so hard that no tool could be made to cut them, and we had great difficulty with them. The guide shoes were subsequently fitted with white metal and with special arrangements for supplying oil, and the result was that we had not the least trouble even with a working velocity of 850 feet per minute."

It may be remarked that precisely this condition of affairs existed on the trial of the *Charleston.*

In addition to these mishaps, it was found that while the air-pump, a single-acting bucket plunger, was effective in maintaining a vacuum of from 26 to 27 inches of mercury at speeds of engine up to 90 revolutions, its capacity was too small when running at high speed, and, as a consequence, the vacuum fell to 22 inches, which is about the same as that maintained by the *Naniwa-Kan* in her trial over a 9.6-knot course.

Before another trial is made a number of alterations will be made, including new vertical air-pumps, new cross-head guides and shoes, and alterations in thrust bearing.

The machinery of the *Charleston* was designed to develop 7,500 I. H. P. under forced draft with the main engines making about 124 revolutions per minute. The engines are of the two-cylinder

compound type, the diameter of the cylinders being 44 and 85 inches, and the stroke 36 inches. There are six main boilers in two water-tight compartments, with fire rooms athwartships, the uptakes of all leading to a common smoke-pipe. Three of the boilers are 11 feet in diameter and three 11 feet 6 inches, all 19 feet 3 inches long, and containing 15,600 square feet of heating surface; there is, besides, an auxiliary boiler with 400 square feet of heating surface.

The maximum I. H. P. developed on trial by the *Charleston* was about 5,500, but it is confidently believed by the builders that the contract power will be developed on the next trial.

Petrel.—Gunboat building by the Columbian Iron Works and Dry Dock Company. After the dock trial and one or two preliminary runs, she was reported ready for the official trial, and left the works on the 13th of July. After the completion of the turning trials, she was, on the 15th, put to the official test in Chesapeake Bay, but after running for about fifteen minutes the primary radius bar of the low-pressure valve gear broke, and she returned under the high-pressure engine making about seven knots.

After repairs were completed, she went out on the 18th of July, but owing to the inability of the firemen to keep up the steam pressure the trial was not continued. Another attempt was made on the 20th, but she failed again for want of good firemen and proper coal. The maximum I. H. P. on this trial was 1,362.

Yorktown.—This vessel went to sea July 27th for the purpose of testing her battery and undergoing the trial required by the contract preliminary to final acceptance. No attempt was made to have a full speed trial, the instructions to the Board being not to put her to any severe tests. She returned on the 29th, and is now preparing for the measured mile and turning trials in Narragansett Bay.

Boston.—On the 3d of August the trials of this vessel were commenced in Narragansett Bay, but before being finally completed were brought to a sudden termination by the ship striking a reef, injuring her hull to such an extent as to make it necessary to return to the New York navy-yard for repairs.

The mean of the four runs at full power was 15.55 knots and 3,854.8 I. H. P. of main engines only.

Atlanta.—Following close upon the trials of the *Boston* came those of the *Atlanta*, but her trials at full power were not concluded, owing to a failure of the feed pumps.

2,000-TON CRUISERS.—Three of these ships were appropriated for at the last session of the 50th Congress, and bids for their construction will be opened on the 22d of August.

They are twin-screw vessels of the following dimensions: Length on water-line, 257 feet; beam, 37 feet; depth amidships, 19½ feet; mean draft, 14½ feet; displacement at this draft, 2,000 tons; immersed midship section, 665 square feet; displacement per inch of immersion at water-line, 15¼ tons. The coal capacity at the above draft is 200 tons, but the bunkers have a capacity of 435 tons.

The engines, designed by the Bureau of Steam Engineering, are of the vertical triple-expansion type, with cylinders 26½, 39 and 63 inches diameter by 26 inches stroke, each set of engines in a separate water-tight compartment. The crank shafts are interchangeable, the engine frames and bed plates of cast steel, and the valve gear of the double-bar link type. There are five cylindrical return tubular boilers, designed for a working pressure of 160 pounds per square inch; three of them are double-ended and two single-ended—all 11 feet 8 inches in diameter, with two 42-inch furnaces at each end. Two of the double-ended boilers are 18 feet 8½ inches long, and one 18 feet 1 inch, the single-ended ones being 9 feet long. The total grate surface is 366 and the heating surface 10,966 square feet.

The engines are designed to develop 5,400 I. H. P., with forced draft, and the contract requires a mean speed of 18 knots to be maintained for four consecutive hours, with premium for increased and penalty for decreased speed. The time fixed for the completion of the ships is two years.

The battery determined upon is two 6-inch and eight 4-inch rapid fire guns, the 6-inch guns being mounted on the poop and forecastle. The secondary battery includes two 6-pounder and two 3-pounder rapid fire guns, two revolving cannons and one Gatling gun. Six torpedo tubes will be fitted.

Torpedo Boat.—The boilers for this boat, building by the Herreshoff Manufacturing Co., will, at their own request, be of the Thorneycroft type.

ENGLAND.—*Trafalgar.*—A twin-screw battle-ship of the following dimensions, built at the Portsmouth dock yard:

Length between perpendiculars,	345 feet.
Beam,	73 feet.
Mean draft,	27 feet 6 inches.
Displacement,	11,940 tons.

The machinery was designed by Messrs. Humphrys & Tennant, the engines being identical with those of the *Victoria* described on page 84 of No. 1, the cylinders being 43, 62, and 96 inches diameter by 51 inches stroke, the boiler pressure being 145 pounds. The screws are four-bladed, 16 feet 6 inches diameter and 21 feet 3 inches pitch.

The natural draft trial of four hours' duration, was made on the 23d of June, with the following results, the ship having been brought down to her designed load draft:

Boiler pressure,	133
Revolutions,	85½ and 86
Vacuum,	27 and 27½
I. H. P.,	8,481
Speed,	16.271

The forced draft trial took place on the 2d of July, the mean results for four hours being—

Steam pressure,	134
Vacuum,	27
Mean pressure, H. P. cylinders,	52.2 and 53.5
Mean pressure, I. P. cylinders,	28.3 and 28.7
Mean pressure, L. P. cylinders,	13.8 and 14.1
Revolutions,	95
I. H. P.,	12,818
Speed on measured mile,	17.282

It has been found that when fully equipped, the *Trafalgar* will draw one foot more than she was designed for, and that her displacement will be 12,460 tons.

Galatea.—On the 19th of July this vessel suffered a breakdown of her machinery, serious enough to prevent her taking part in the manœuvres.

Medea.—This vessel, described on page 87 of No. 1, has, since the completion of her contractors' trials, been given a trial at sea, the run being from Spithead to Gibraltar, during which an average speed of 16 knots was maintained, the conditions all being favorable. The return trip was made at slower speed; and it has now been discovered that her boiler tubes need so much attention as to make it doubtful that she can take part in the naval manœuvres.

Medusa.—This vessel, after delivery to the Government, was subjected to a series of trials with different screws, those originally designed having failed to give the speed for which the ship was intended, although the indicated horse-power on trial was in excess of that fixed from the experiments with the models. The trials of the screws were made at speeds of 10, 12 and 16 knots, and at full speed, and all were made on the measured mile. The following are the results at full power, all of the screws being three-bladed:

Diameter of screw, .	12′ 3″	13′ 6″	12′ 3″
Mean pitch, .	17′ 3″	17′ 0″	17′ 3″
I. H. P., . .	9,975	10,011	9,901
Speed, .	19.574	19.924	19.717

Although the second screw gave very good results at high speed, it did not do as well as the others at low speed.

On account of the *Medea* being a very wet ship, the bower and sheet anchors in this ship have been moved further aft, with a view to reducing her pitching.

Magicienne.—The trials of this vessel, some of which were recorded in the last number of the JOURNAL, page 178, have been attended with many mishaps.

On the 7th of May, after alterations and modifications in the back connections of her boilers and in the exhaust pipes and condensers, she was subjected to another trial under forced draft, the mean result being 7,740 I. H. P. and 18.42 knots, and the maximum I. H. P. 8,100.

Another trial was made on the 8th of June, but after running for three hours it had to be discontinued on account of priming, the I. H. P. being 8,780 and the speed 18.85 knots, with 138 revolutions of the engines.

Her final trial took place on the 15th of June and was successful, the results being:

Steam pressure,	148
Vacuum,	23¼ and 24
Revolutions,	144 and 143.2
I. H. P.,	4,516 and 4,746
I. H. P., collective,	9,262
Speed, measured mile,	19.126

Before this trial the pitch of the screws was reduced from 17 feet 9 inches to 17 feet, but the speed still fell far short of the 19¾ knots for which the ship was designed.

The general opinion of the vessels of the "*M*" class (*Medea*, *Medusa*, *Marathon*, *Magicienne* and *Melpomene*), so far as relates to their machinery, is that they have too little boiler power. Before the completion of the trials the grate surface was increased in all of these vessels.

Marathon.—A sister ship to the *Magicienne*, and engined by the same firm, after having alterations made similar to those found to be necessary in the *Magicienne*, had a successful trial with natural draft on the 27th of May, the mean speed for twelve hours being 17½ knots.

On her forced draft trial the results were:

Steam pressure,	146
Vacuum,	22.75 and 24.43
Revolutions,	142.76 and 145.3
I. H. P.,	4,423 and 4,357
I. H. P., collective,	8,780
Speed on measured mile,	18.591

Although the collective I. H. P. was below the contract power of 9,000, inasmuch as the power developed during the last hour of the trial was in excess of 9,000, the trial was considered satisfactory.

Melpomene.—Protected sheathed cruiser of the same dimensions as the *Magicienne*, described on page 178 of No. 2, designed for a speed of 19¾ knots.

The engines, built by the Palmer Ship-Building Company, are of the same size as those of the *Magicienne*—cylinders 34½, 51, and 76½ inches diameter by 36 inches stroke, working with a boiler pressure of 155 pounds. She has four double-ended boilers 12 feet 3 inches diameter and 18 feet 4 inches long, each boiler containing six 38-inch furnaces; the total grate surface as originally designed was 450 and the heating surface 13,970. Her screws are 12 feet 3 inches diameter and 17 feet 3 inches pitch, with a developed area of 45 square feet each.

Her first trial was unsuccessful, on account of defects in the valve gear, and the next one, on the 29th of May, on account of a fan engine breaking down.

The twelve-hours' natural draft trial took place on the 18th of June, with the following results:

Steam pressure,	141 pounds.
Vacuum,	24 inches.
Revolutions,	128
I. H. P.,	6,216
Speed, measured mile,	17.383
Speed, mean, by patent log	17.67

The four-hours' forced draft trial was concluded on the 22d of June, the vessel having been brought down to her designed draft of 17 feet 6 inches. The following are the results:

Steam pressure,	152 pounds.
Vacuum,	23.5 inches.
Revolutions,	143.6
Air pressure in fire-rooms,	1.7 inches.
I. H. P.,	9,641
Speed, measured mile,	19.7 knots.
Speed, patent log,	19.6 knots.

"Machinery in the Navy is well nigh as important as guns or the ships themselves. If, therefore, in these days there is any-

thing unsatisfactory about it, it becomes a very serious matter, indeed, militating most deplorably against our naval efficiency. The numerous abortive attempts that were made to wring the stipulated power out of the *Magicienne*, while other similar ships only obtained it by the skin of their teeth after a severe struggle, were, of themselves, sufficient to show that there was something radically wrong somewhere; and of far more telling effect as an indication of faulty design is the recent miserable performance of the *Medea*, a cruiser of the same class. This vessel, which is not sheathed with wood as some of her sisters are, was expected to steam at a speed of 18 knots with natural draft, and had she proved herself capable of this, would have been one of the most useful of the smaller fighting ships in our own or any other navy. To see what she could really do at sea with her own crew, she was sent on a cruise to Gibraltar and back with the result that she broke down badly enough to be detained more than a week for repairs, and that during a continuous run—we do not yet know for how long—made under most favorable circumstances, she only averaged 16 knots, we presume, with natural draft. It would be of very great public service if some Member of Parliament would move that her log and engine room register for this cruise be printed. It would be infinitely more useful and interesting than many Parliamentary papers, and the value of such a return would be still higher if her captain and chief engineer were invited to express their opinions as to her capabilities.

"The cause of all the trouble, worry, and anxiety that have been occasioned by the propelling machinery of the "M" class is not far to seek. It has been pointed out in these columns over and over again. It is the extreme lightness of construction, verging on the dangerous, which is rendered necessary by the determination of the shipwrights not to allow sufficient space in the ship for the horse-power they demand from the engineering contractors. Extreme speed is a very good thing in its way, but a proper proportion of tonnage must be given up, that it may be secured without such misery and straining as in the case of the ships we have been considering. It is the boilers that are most in fault. To the insufficiency of heating, and especially of grate surface, most of the trouble may be ascribed. Of the three "M" cruisers tried at Portesmouth, not one indicated the specified horse-power till the contractors had increased the fire-bar area. It must acknowledged, however, that the advocates of extreme lightness of scantling have arguments on their side of considerable force, of which they are naturally not slow to avail them-

selves; but we maintain that they are void and of no effect against the disadvantages and dangers exhibited in actual practice. It is all very well to say that such and such a rod or plate is, according to all the laws of science, quite thick enough for its purpose, and that to add anything to its strength would be clumsy and show bad engineering; but suppose, after all, the rod or plate snaps or bends, how then?—and a small defect in manufacture or quality of metal, impossible to discover till an accident has happened, may bring this about. Again, there is the very important human factor to be taken into consideration—modern machinery requires increasing watchfulness and skilled labor of the very highest description to keep it going and in going order. Even supposing we have those qualities in the *personnel* of the Navy—and we do not say we have not—the best man that ever lived is liable to an error or oversight sometimes, and a mistake that would a short time ago have had but trifling consequences, may now mean the complete disabling of the engines. The more space you can save out of the engine room the more coal you can carry in your bunkers, and this is always a sore temptation to the designer, now that coal endurance has become so important an element in the efficiency of a fighting ship since the abolition of sails; but any amount of coal is of no use if your boilers, too weak and too small, have been crippled by the use of that pestilent forced draft.

"The long and the short of it is, that, if you want good speed and good machinery to produce that speed, you must build your ships large enough to hold your engines, and everything else besides. It was with unmixed satisfaction that we noted that the improved *Medea*, though 600 tons larger than the present "M's," are only to carry engines of the same horse-power; and with equal satisfaction we have learned that part of the additional tonnage is to be allotted to the machinery department. It may, therefore, be hoped that the new ships will really steam 18 knots with natural draft when wanted, and not drop down to 16 knots as soon as they are put to a seagoing test. Comparisons have often been made, and often unjustly, by persons of defective information, between the performances of the fast ships of the Royal Navy and the mercantile marine. The different conditions that obtain in the two services were frequently ignored; but, for the life of us, we cannot see why these conditions should not for once in a way be assimilated so far as to order one of the belted cruisers to disregard everything but speed, and send her on a cruise from Queenstown to New York and back. We know what they did on their trials; it would be a blessing to know what they can

do on a voyoge that would be nothing out of the way in war time. If, as we believe the *Undaunted* or *Narcissus* would not average 15 knots for the 6,000 miles, it would manifestly be imperative to find out the reason why she did so much worse than a third-class mail steamer.

"The case of the *Galatea* is quite different, and more serious in proportion to the greater importance of the ship. When undergoing her contractors' trials on the Clyde, before she was brought down South to be handed over to the Government, the whole of the slide-gear of one engine collapsed and crumpled up, and such a scene of ruin as that engine-room presented has rarely been witnessed. The extremely complicated gimcrack nature of the system of slide-gear adopted was universally believed by naval engineers to be the cause of the break-down. It was, however, merely replaced, not altered, and, as was often remarked at the time, there was really no reason why the new gear, or the gear of the other engine, should not at any moment give way in a precisely similar manner. Now, we learn that part of this gear—the eccentrics, to wit—got red-hot on the way from Portsmouth Harbor to Spithead and broke up into fragments when water was applied—which, by-the-way, it might naturally have been expected to do. It is said that, by working continuously day and night, the *Galatea* will take her place in the inspection; but neither her Captain nor Chief Engineer is to be envied. It is pleasant to find that the performances of the *Trafalgar* were, like those of almost all our newer ironclads, eminently satisfatory; but speed, though important, is not such a *sine quâ non* in them as in the cruisers, and it is of these latter that we want to be satisfied that not only can they begin by making 18 knots, but can go on at it as long as their coal lasts; and, at present, it is not doubtful, but certain, that none of them can do it."—*Army and Navy Gazette.*

Lapwing.—Gunboat, similar to the "*P*" class described on page 85 of No. 1.

Length between perpendiculars, . .	165 feet
Beam, ...	31 feet
Mean draft, ...	11 feet 7½ ins.
Displacement, ...	805 tons.

The ship and engines were built at the Devonport dockyard the engines being a duplicate of those of the "*P*" class—20, 30,

and 45 inches diameters of cylinders, by 24 inches stroke, working at a boiler pressure of 140 pounds.

On the 22d of June she had an unsatisfactory trial under natural draft owing to leaky boiler tubes in the fifth hour. The mean results for four hours were:

Steam pressure,	130 pounds.
Vacuum,	27½ inches.
Revolutions,	163
I. H. P.,	816
Speed,	12.8 knots.

The next trial was on the 2d of July, but was again unsuccessful at the end of 8½ hours, from the same cause as the previous one.

The third trial was also unsuccessful, the boiler tubes giving out in the fifth hour.

Magpie.—A sister vessel to the *Landrail* completed her trials in May, both trials being successful. The I. H. P. with natural draft was 822 and the speed 12.38 knots; with forced draft 1,298 I. H. P. and 14.13 knots, the revolutions being 184.4.

The machinery of this vessel was constructed by the Earle Shipbuilding Co.

Grasshopper.—Twin-screw torpedo gunboat, 200 feet long, 28 feet beam, 8 feet 9 inches draft, and of 525 tons displacement.

The engines are of the vertical triple-expansion type, with cylinders 18½, 27 and 42 inches diameter, by 18 inches stroke, working at a boiler pressure of 140 pounds, and designed for 3,000 I. H. P. with forced draft. The speed expected with this power is 19 knots.

On the 14th of May she had an unsatisfactory trial, due to her boilers priming, and another unsatisfactory one on the 25th of June, due to leaky boiler tubes.

A forced draft trial on July 17th failed on account of a breakdown.

The last trial took place on July 22d. The I. H. P. did not quite come up to 3,000, but the trial was considered satisfactory. However, after coming to anchor, boiler tubes commenced to leak.

The following is from one of the English service journals:

"The troubles experienced with these swift torpedo gunboats show very clearly that too much reliance is being placed upon the forced draft in developing the power necessary for the attainment of a useful speed."

As indicated on pages 171 and 172, this vessel took part in the naval manœuvres last summer, and before the final completion of her machinery trials. After the manœuvres her hull was strengthened, it having been demonstrated that the hulls of the vessels of this class were too weak.

Sharpshooter.—Twin-screw, torpedo gunboats of the following dimensions: Length, 230 feet; beam, 27 feet; mean draught, 8 feet 3 inches; displacement, 735 tons.

Her engines, designed by Bellis & Co., are of the vertical triple-expansion type, with cylinders 22, 33 and 49 inches diameter by 21 inches stroke, and were designed for 4,500 I. H. P. under forced draft, with a piston speed of about 1,100 feet per minute. The I. H. P., with natural draft, is expected to be 2,500. Steam, at a pressure of 155 pounds, is supplied by four "wet bottom" locomotive boilers. The coal capacity is 100 tons.

After various alterations with a view to strengthening her hull, she was sent out for trial on the 26th of April, but it was unsuccessful. Another attempt was made on the 6th of May, but the tubes in one of the boilers gave out, necessitating the hauling of fires. A week later there was another unsuccessful trial. Again, on the 29th of May, her valve gear broke, and the trial had to be discontinued.

The next trial, with natural draft, was on the 4th of June, but this also was unsuccessful, the excessive vibration of the vessel breaking the steam pipe leading to the steering engine.

She went out again on the 6th of June, but this time the star board main steam pipe burst.

On the 24th of June a lever of the reversing gear broke during the fifth hour, and an eccentric rod in the ninth hour, which stopped the trial. The mean results of this trial, for eight hours, were:

Steam pressure, ...	125
Vacuum, ...	27

Revolutions,	249.75 and 241.8
I. H. P.,	1,375 and 1,304
I. H. P., collective,	2,679

A forced draft trial was attempted on the 17th of July, but it was unsatisfactory, owing to leaky boiler tubes.

The vessels of the Mediterranean squadron recently had a full speed trial of four hours' duration, the mean speed by patent log being given below, together with the speed at which each ship is rated:

Benbow,	15.37	16.75
Scout,	14.50	17.00
Phaeton,	14.25	16.5
Colossus,	14.13	15.4
Edinburgh,	12.75	15.5
Temeraire,	12.63	14.6
Dreadnaught,	12.00	14.2
Landrail,	——	14.0

In the case of the *Landrail*, whose boilers have given considerable trouble ever since she has been on the station, it was found impossible to keep up a speed of 11 knots.

During the trial the wind was nearly ahead, with a force 4, and there was a moderate swell, which seemed to tell on the cruisers.

ITALY.—*Piemonte.*—The trials of this cruiser have been satisfactorily concluded, with the following results:

	Natural draft.	Forced draft.
Duration of trial,	4 hours.	1½ hours.
Speed in knots,	20.4	22.0
I. H. P.,	7,040	12,700

For a short while the speed is reported to have been 22.3 knots.

Previously to this trial, there had been considerable trouble with the lubrication, and also with the boilers.

As the final results above given do not agree very well with the results given in Mr. Watts' Paper, and published on page 181 of No. 2, it is fair to assume that the final trials were made at lighter draft than those first published.

THE ENGLISH NAVAL MANŒUVRES.

These annual manœuvres, which do so much towards demonstrating the worth of the ships of the English navy, and of their machinery, and which form such an admirable school of instruction for the officers and men, commenced on the 11th of August.

This year the operations will be devoted to the attack and the defenses of the English coast, the hostile (Achill) fleet having its headquarters at Queenstown and Bantry Bay, Ireland, and the defense squadron being subdivided into six distinct squadrons, as follows:

"B" Squadron of Attack. (Achill.)

Battle-ships.	Speed.	Dispt.	Armament.	Men.
Northumberland,	11.5	10,780	7 12-t.; 20 9-t.	710
Camperdown,	15.5	10,600	4 67-t.; 6 5-t.	500
Devastation,	11.8	9,330	4 35-t.	357
Hero,	13.5	6,200	2 45-t.; 4 5-t.	290
Anson,	15.4	10,600	4 67-t.; 6 5-t.	520
Howe,	14.9	10,300	4 67-t.; 6 5-t.	500
Inflexible,	11.5	11,880	4 80-t.; 6 26-cwt.	460
Monarch,	12.8	8,320	4 25-t.; 2 12-t.; 1 6½-t.	560
Iron Duke,	11.0	6,010	10 12-t.; 6 26-cwt.	482
Cruisers.				
Immortalité,	17.5	5,600	2 22-t.; 10 5-t.	440
Australia,	16.8	5,600	2 22-t.; 10 5-t.	440
Mersey,	16.0	4,050	2 15-t.; 10 5-t.	300
Arethusa,	15.0	4,300	10 5-t.	281
Calypso,	11.9	2,770	4 5-t.; 12 36-cwt.	312
Iris,	16.0	3,730	13 40-cwt.	271
Magicienne,	16.5	2,950	6 5-t.	193
Nymph,	13.5	1,140	8 40-cwt.	136
Curlew,	12.0	950	1 5-t.; 3 40-cwt.	97
Torpedo Vessel.				
Hecla,		6,400		

TORPEDO GUN-BOATS.				
Grasshopper,	17.2	525	1 25-cwt.	61
Rattlesnake,	17.2	550	1 25-cwt.	61
Seven Torpedo boats,			4 R. F. guns.	16
One Torpedo boat,			4 R. F. guns.	21

"A" SQUADRON OF DEFENCE. (British.)

BATTLE-SHIPS.	Speed.	Dispt.	Armament.	Men
Hercules,	12.5	8,680	8 18-t.; 2 12-t.; 4 6½-t.; 6 26-cwt.	630
Warspite,	15.7	8,400	4 24-t.; 6 5-t.	514
Conqueror,	13.5	6,200	2 45-t.; 4 5-t.	310
Shannon,	10.5	5,390	2 18-t.; 7 12-t.	454
Collingwood,	14.6	9,500	4 45-t.; 6 5-t.	459
Rodney,	15.0	10,300	4 69-t.; 6 5-t.	500
Neptune,	12.3	9,310	4 38-t.; 2 12-t.	538
Ajax,	11.0	8,660	4 38-t.; 2 5-t.	382
Invincible,	11.5	6,010	10 12-t.; 6 26-cwt.	479
Northampton,	11.2	7,630	4 18-t.; 8 12-t.	470
Rupert,	12.0	5,440	2 22-t.; 2 5-t.	237
Black Prince,	10.8	9,210	4 9-t.; 22 6½-t.; 2 5-t.	697
CRUISERS.				
Undaunted,	16.9	5,600	2 22-t.; 10 5-t.	440
Galatea,	17.0	5,600	same.	440
Narcissus,	17.0	5,600	same.	440
Aurora,	16.9	5,600	same.	440
Forth,	15.5	4,050	2 14-t.; 10 5-t.	300
Thames,	15.8	4,050	same.	300
Mercury,	15.5	3,730	13 40-cwt.	276
Marathon,	17.7	2,950	6 5-t.	193
Melpomene,	17.7	2,950	same.	193
Medea,	16.0	2,800	same.	193
Serpent,	15.3	1,770	same.	156
Mohawk,	15.3	1,770	same.	156
TORPEDO GUNBOATS.				
Sharpshooter,	19.0	735	2 25-cwt.; 7 36-pdr.	61
Sandfly,	17.0	525	1 25-cwt.	61

Spider,	17.0	525	1 25-cwt.	61
Nine torpedo boats,			4 R. F. guns.	16
One torpedo boat,			6 R. F. guns.	21

"C" Squadron of Defence. (Lamlash Bay.)

	Speed.	Dispt.	Armament.	Men.
Hotspur,	10.5	4,010	2 25-t.; 2 5-t.	224
Belleisle,	10.0	4,870	4 25-t.	231
Cyclops,	9.0	3,560	4 18-t.	166
Gorgon,	9.0	3,560	4 18-t.	191
Hecate,	9.0	3,560	4 18-t.	191
Herty,	15.0	1,300	4 25-cwt.	60
Plover,	12.0	755	6 25-cwt.	50
Four torpedo boats,			4 R. F. guns.	16

"D" Squadron of Defence. (Plymouth.)

	Speed.	Dispt.	Armament.	Men.
Inconstant,	13.3	5,780	10 12-t.; 6 6½t.	618
Racoon,	15.3	1,770	6 5-t.	156
Prince Albert,	9.0	3,880	4 12-t.	200
Six torpedo boats,			2 to 4 R. F. guns.	

"E" Squadron of Defence. (The Downs.)

	Speed.	Dispt.	Armament.	Men.
Volage,	13.1	3,080	10 4-t.; 2 64-pdr.	338
Glatton,	9.5	4,910	2 25-t.	191
Hydra,	9.0	3,560	4 18-t.	166
Trent,	7.0	363	3 4½-t.	25
Slaney,	7.0	363	2 64-pdr.	25
Medway,	7.0	363	3 64-pdr.	25
Six torpedo boats,			2 to 4 R. F. guns.	

"F" Squadron of Defence. (Hull.)

	Speed.	Dispt.	Armament.	Men.
Ruby,	11.5	2,120	12 6-pdr.	260
Tartar,	15.6	1,770	6 5-t.	156
Elk,	8.0	603	1 4½-t.; 1 64-pdr.	60

Medina,	7.0	363	3 64-pdr.	25
Two torpedo boats,			4 R. F. guns.	16

"G" SQUADRON OF DEFENCE. (Leith.)

	Speed.	Dispt.	Armament.	Men.
Active,	13.1	3,080	10 4-t.; 2 64-pdr.	374
Medusa,	16.5	2,800	6 5-t.	193
Pigmy,	12.5	755	6 25-cwt.	50
Spey,	7.0	363	3 64-pdr.	25
Tees,	7.0	363	3 64-pdr.	25
Watchful,	8.0	560	2 5-in.; 2 4-in.	40
Two torpedo boats,			4 R. F. guns.	16

Of the vessels in the "*C*" squadron, the *Hotspur* and the *Belleisle* are battle-ships, the *Cyclops*, *Gorgon*, and *Hecate* coast defense vessels, and the *Hearty* and *Plover* gunboats, the last one being a new vessel.

In "*D*" squadron the *Inconstant* and the *Racoon* are cruisers, and the *Prince Albert* a coast defense vessel; the *Racoon* is a sister vessel to *Serpent* in "*A*" squadron.

"*E*" squadron has one cruiser, the *Volage*, two coast defense vessels, and three small gunboats.

The *Ruby* and the *Tartar* in "*F*" are cruisers, and the *Elk* and *Medina* gunboats.

In "*G*" the *Active* and *Medusa* are cruisers, the others gunboats, the *Pigmy* being the only one of recent date.

On comparing the "*A*" and "*B*" squadrons it will be seen that "*A*" is stronger both in battle-ships and cruisers, especially so in the latter.

The speed column gives what each ship is supposed to maintain at sea with natural draft, and is approximately near the trial speeds of the different ships under such conditions. There are a few whose speed is overrated, while some are put down too low when compared with their trial performances. For instance, the *Nymphe*, *Pigmy*, and *Plover* are rated too high, while the *Magicienne*, one of the new "*M*" class of 19¾-knot cruisers, is over a knot slower than the *Marathon* and the *Melpomene*, vessels identical in construction with her. Similarly the *Medea*, designed

for a 20-knot ship, is put down at 16, which is the average speed she maintained on her run to Gibraltar.

Altogether, the array of ships is very formidable, and the experience gained from such manœuvres cannot fail to produce good results.

COMBINED INDICATOR CARDS OF *YORKTOWN*.

At the request of several correspondents, we give a brief description of the method of constructing the diagram which forms the third plate in the article on the *Yorktown* in the last number of the JOURNAL, commonly known as the "combined card" of the engine. Vertical ordinates represent pressures above perfect vacuum; the abscissal represent volumes.

The volume of the high-pressure cylinder up to the point of cut-off and the volume of its clearance having been determined, a distance equal to the sum of these two on the scale of the diagram is laid off on a line whose vertical ordinate is the initial pressure in the cylinder above a perfect vacuum. The point thus determined is the beginning of the two curves shown, marked pv = constant and $pv^{\frac{10}{9}}$ = constant. These can be laid out graphically, or, by the aid of tables of pressures and volumes, by finding a series of points by calculation.

It is this initial volume of steam which expands through the various cylinders (neglecting compression), and the object of the diagram is to find how near the actual cards from the cylinders, when laid out to the same scale, agree with these curves of hypothetical expansion.

The card of each cylinder is laid off by placing its initial line at a distance from the line of no volume equal to its clearance. At any point, then, the abscissa of the card represents the total actual volume of the steam up to that point. Thus, the steam which originally occupied a volume equal to the high-pressure cylinder up to cut-off plus its clearance, finally occupies (omitting compression) the entire volume of the low-pressure cylinder plus its clearance.

Inasmuch as the hypothetical curves do not represent any actual performance, we do not from this diagram get any actual percentage of efficiency; but the diagram is of value as giving a simple and easily-constructed standard of reference, from an inspection of which we can learn a good deal about the distribution of the steam throughout the engine, and can thus quickly compare the performance of one engine with another on this basis.

For some other methods of laying out the "combined card" and hypothetical curves, the reader is referred to the article on the performance of the S. S. *Meteor*, by Prof. Kennedy, in Engineering, for May 10, 1889, p. 530.

MERCHANT STEAMERS.

Augusta Victoria.—This vessel, built for the Hamburg-American Packet Company by the Vulcan Works, Stettin, Germany, is a sister ship of the *Columbia*, described on page 168, of No. 2. The engines are twin-screw, vertical, triple-expansion, designed for 12,500 I. H. P., and working with a boiler pressure of 157 pounds. The cylinders are 41.3, 66.9 and 106.3 inches in diameter, by 63 inches stroke. Steam is supplied by eight double-ended cylindrical boilers placed in three separate water-tight compartments, and working with a light forced draft, the fans discharging air into open fire-rooms. The total grate surface is 1,120, and the heating surface 36,000 square feet. The speed of the vessel on trial is said to have been 20 knots per hour.

On her first trip she made the run from Southampton to Sandy Hook in 7 days, 2 hours and 30 minutes, making the fastest first trip on record, the average speed being 17.9 knots, and the revolutions reported as 77. The daily runs, omitting the runs on the portions of the first and last days, were 434, 410, 441, 435, 464, and 452 knots.

The Hamburg-American Packet Company's steamer *Columbia*, described on page 168 of No. 2, completed her first westward voyage on the 26th of July, making the voyage from Southampton to Sandy Hook in 6 days, 23 hours and 5 minutes, which is

the fastest time on record between those points, and, allowing for the difference between Southampton and Queenstown, is the fastest first voyage on record. Her average speed was 18.7 knots per hour. The return voyage was made in 6 days, 19 hours, and 19½ minutes.

The *City of Paris*, on the 31st of July, completed another fast westward voyage, the time being 5 days, 23 hours and 10 minutes, just three minutes behind her record. The daily runs were as follows: 438, 500, 491, 496, 492, 380.

On the 13th of August she completed the fastest eastward passage on record—5 days, 23 hours and 40 minutes.

OBITUARY.

Charles Gratiot Talcott.

The sudden death of Assistant Engineer Talcott, on board the *Atlanta* at the New York Navy-Yard, on the 25th of July, was a shock to his many friends in the Navy and in civil life, to whom he had endeared himself by his sterling qualities. An attractive presence and an amiable disposition, made him a favorite wherever he was known, and by his death the Engineer Corps has lost a valuable young officer and the service one of its brightest ornaments.

Born Sept. 14, 1859, he entered the Naval Academy in 1875, when just sixteen, and though next to the youngest member of the class, he always held a high rank, and was regarded as a bright and capable student. After graduation in 1879, he made his first cruise in the *Shenandoah* on the South Atlantic Station. Upon its completion, he was on duty for a time at the Washington Navy-Yard, and afterwards was Secretary of the Navy-Yard Commission. He then started out in the Trenton, but owing to an accident was detached and subsequently ordered to the *Ossipee*, on which he made a cruise on the China station. After his return his duty was in the Bureau of Steam Engineering until November 25, 1888, when he was ordered to the *Atlanta*, where he continued on duty until his death.

His taste for engineering was inherited, both his father and grandfather having been civil engineers.

Erratum.—Page 278 of No. 2, 14th line, "five" should be "four."

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